L8E9L

MATRICULATION ASTRONOMY.

INTRODUCTORY MATTER.

1. What is Astronomy? Into how many branches is it divided, and what is the scope of each branch?

Astronomy is the science which treats of the heavenly bodies. It investigates their motions and the laws which govern them; their magnitudes, distances, constitution, and physical condition; the influence they exert upon one another either by attraction or radiation, or in some other way; in short, the causes of all their various phenomena.

It is divided into two branches, Physical and Practical.

Physical Astronomy is that branch of Astronomy which treats of the causes of the motions of heavenly bodies.

Practical Astronomy is that branch of Astronomy which shows how astronomical observations are made, what instruments are used, and by what calculations the results are deduced.

THE EARTH.

2. Explain the terms Globe, Great Circle, Small Circle, Axis, Poles, Equator, Latitude, Parallels of Latitude, Meridian, and Longitude. Illustrate your answer by means of a diagram.

A *Globe* or *Sphere* is a solid body with an endless surface, every point in which is equidistant from the centre.

A *Great Circle* is a circle traced round a globe so as to divide it into two equal parts. All other circles traced upon a globe so as not to divide it into two equal parts are called *Small Circles*.

The *Axis* of the Earth, or *Polar Diameter*, is an imaginary line which passes through its centre, and on which it seems to turn.

The two extremities of the Earth's Axis are called the *Poles*, the one at the north being the North Pole, and the other the South Pole.

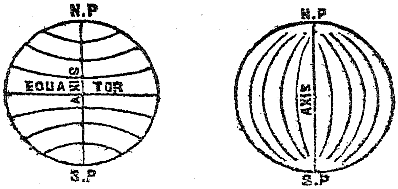
The *Equator* is the great circle drawn round the globe at an equal distance from the two poles.

The *Latitude* of a place is its distance north or south from the equator. Astronomically, it is the angle made by the direction of gravity at that place with the plane of the earth's equator.

Parallels of Latitude are circles—not great circles—which are drawn parallel to the Equator, between it and each of the poles.

A *Meridian* is a semicircle drawn from the North to the South Pole, cutting the Equator at right angles. All places on the same meridian have mid-day at the same time. (Lat. *meridies*, midday or noon.)

Longitude is the distance of a place east or west from a given meridian, which is taken as the standard of measurement. (Fig 1.)



Parallels of Latitude. Meridians.

Fig 1.

3. How are Latitude and Longitude measured ?

To measure the latitude of a place (*i e.* its distance north or south from the equator), the space between the equator and each pole is divided into 90 parts called *degrees* of latitude (marked °). Each degree is subdivided into 60 minutes (′), and each minute into 60 seconds (″). Thus Bombay is in latitude 18° 53′45″ north of the equator. Again, one degree of latitude contains about 69 miles; so that Bombay is, roughly speaking, 69 × 19, *i.e.* a little more than 1,300 miles north of the equator.

Note.—The length of a degree of latitude is not the same in all parts of the earth. Actual measurement has shown that it increases towards the poles, the difference between the equatorial and polar degrees of latitude being nearly three-fourths of a mile. The reason is that the earth is not a perfect sphere but an oblate spheroid (see Ques. 7), like an orange, flattened at the poles and bulged out at the equator.

To measure longitude each nation takes as its standard that meridian which passes through or near its capital city. Thus the English reckon longitude from the meridian passing through Greenwich near London, the French through Paris, and so on. The circumference of the globe along the equator is divided into 360° of longitude, each degree being subdivided into 60 minutes, and each minute into 60 seconds. To illustrate:—Greenwich is said to be in 0° longitude; Bombay, which is 72° east of London, is said to be in 72° east longitude; while New York, which is 75° west of London, is said to be in 75° west longitude.

Note.—A degree of longitude measures about 69 miles at the equator, but gradually decreases in size towards the Poles. This can be readily understood with the help of a ball or school-globe.

4. What are the Tropics, and why are they so called?

The Tropics are two imaginary lines drawn round the globe parallel to the equator at a distance of 23½° on each side of it. The Northern one is called the Tropic of Cancer, and the Southern the Tropic of Capricorn. They form the boundary-lines of the Torrid Zone.

The Tropics are so called because they mark the *trope* or turning-point of the Sun, north and south, from the zodiacal signs, Cancer and Capricorn. Beyond the Tropics the Sun's rays are never vertical. (Fig 2).

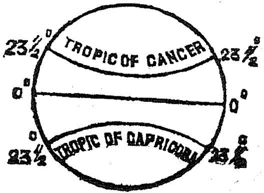


Fig. 2.—The Tropics.

5. What are the zones' on the earth? How many are they? Name them, and draw a figure to illustrate your answer.

The *zones* are those great divisions into which the whole globe is divided with respect to latitude and temperature. They are five in number: the *torrid* zone, extending from tropic to tropic, about 23½° on each side of the equator; two *temperate* zones, situated between the tropics and the polar circles; and two *frigid* zones, situated between the polar circles and the poles, and including the regions within 23½° from either pole. (Fig. 3).

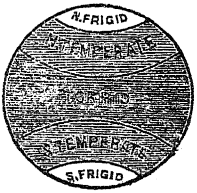


Fig. 3.—Zones.

6. Give as many proofs as you can of the rotundity of the Earth.

(1.) *Ship Proof*:—When a ship is moving away from the shore, the lower part, the broad massive hull, first disappears; then the rigging sinks out of sight; and the slender top-masts go last out of view. And when a ship approaches, the sails and masts first appear, and the hull comes last into view. These things prove that the sea bulges out between the observer and distant objects; that is, that the sea is convex. As this is observed everywhere, it follows that the world is not a flat plain, but more or less round.

(2.) *Circumnavigation Proof*:—Navigators have sailed round the world and come back to the spot they started from, without altering the general direction of their course; just as a fly may be seen to walk round an orange and return to the place from which it started, without retracing its steps.

(3.) *Sun-rise Proof*:—When the sun rises, it does not give light to all the world at once; it shines on part only. It rises earlier at any place than at another place further west. From this it is manifest that the earth is not a flat plain, but that it bulges out, or is round, *from east to west.*

(4.) *Pole-star Proof*:—The pole-star appears higher and higher in the sky the further we go north; and sinks towards the horizon the further we go south towards the equator. At the equator it appears just on the horizon, and south of the equator it can never be seen. This would not happen if the earth were an extended plain, and shows that it is round *from north to south.*

(5.) *Shadow Proof*:—Under certain circumstances, as in eclipses of the moon, the shadow of the Earth may be seen cast out behind it in space, and it then presents the exact outline that the shadow of a globe must bear.

(6.) *Dip-of-the-horizon Proof*:—If a person stands on a vast plain and looks on all sides around him, or if he does so from the deck or mast-head of a ship, or from a balloon high up in the air, he finds that the plain stretched out beneath is bounded by a circular outline, the size of the circle varying with his height above the level of the sea. This happens in all parts of the earth, and the fact is a proof positive of its rotundity, for no other body but a globe would always give a circular out-line when viewed from any point without it. To illustrate this fact, we may suppose a fly on or above the surface of an orange. The fly's vision will always be bounded by a circle of which it is the centre.

(7.) *Proof from analogy*:—All the other heavenly bodies whose shape can be determined appear globular; therefore, the earth, being like them, must be similar in shape.

(8.) *Experimental Proof*:—If three poles be fixed in a straight line on a level plain so that they stand at equal heights above the surface, and if a telescope be sighted along the first to the third pole, the top of the middle pole will be seen higher than the line joining the tops of the first and third. This can be explained only by the curvature of the earth's surface. This experiment has been made in various parts of the earth and the amount of the curve is the same everywhere. Hence the earth's surface is a continuous curve, that is, the earth's form is globular.

(9). *Canal Proof*:—It is a law in nature that "water finds its own level." Hence, if the earth were flat, a canal would have to be dug of the same depth throughout its length. But engineers have experienced that as they approach the middle of a canal they are required to dig deeper and deeper to keep the water at the same level. This shows that the surface of the earth is a gentle curve.

7. Is the Earth a perfect sphere? If not, what is its real shape, and how can you account for the formation of that shape?

The Earth is not a sphere, for the polar diameter is shorter by about 25 miles than the equatorial diameter, the former being about 7900 miles, the latter about 7925. This difference, called the Polar Compression of the earth, though small in itself, still proves that the Earth is not a *sphere*, but what is called an *oblate spheroid* (an orange-shaped solid), quite sensibly flattened at the poles.

How such a shape could have been formed:—Geologists, who examine into the structure, or physical constitution, of the Earth, tell us that there was doubtless a time long, long ago, when the surface of the earth was as hot and luminous as the surfaces of the sun and stars are believed to be even now. They tell us that the Earth at one time was a ball of liquid matter, which gradually cooled down and became solid as we see it now. Now, it is plain that if such a ball of liquid matter be spun on its axis, the parts towards the middle would bulge out, while those near the two ends of the axis, *i. e* the two poles, would be depressed. And this is exactly as we find with the Earth.

8. What is a spheroid? When is it called oblate, and when prolate?

A spheroid is a solid body formed by the rotation of an ellipse on one of its axes; it is *oblate* if it rotates on the minor axis, and *prolate* if it rotates on the major axis.

9. How is it proved that the earth is an oblate spheroid and not a perfect sphere?

That the earth is an oblate spheroid and not a perfect sphere, is proved by the fact that degrees of latitude increase gradually in length from the equator to the poles.

10. What appearance would the Earth present in general to a spectator on the Sun's surface?

To a spectator on the sun's surface,—if indeed such a one be possible, or if he have the power of vision strong enough to see a body so comparatively small at the almost inconceivable distance of 92 millions of miles,

—our Earth would appear, not as a ball that it is, but as a *flat* circular plate of luminous matter, just as the sun or moon appears to us.

11. Mention all the motions of the Earth, and state, without explaining, the various natural phenomena produced by them.

The Earth is known to have four different motions in all: (1) Rotation on its own axis; (2) Revolution round the sun; (3) Motion of the axis round the pole of the ecliptic called "Precession"; and (4) A forward movement in space, along with the sun and the other planets, towards the Constellation Hercules.

Consequences of the earth's rotation:—(i) The apparent movement of the heavenly bodies in an opposite direction, giving rise to the alternate succession of Day and Night.

(ii) Bodies moving from the equator to the poles are deviated towards the east, and those moving from the poles to the equator are deviated to the west. For example, cold currents of wind coming from the North and South Poles to the equator become N. E. and S. E. winds respectively.

(iii) The spheroidal shape of the earth, which is the natural result of the rotation of a semifluid mass.

(6). The well-known 'Foucault's pendulum experiment' has proved experimentally that the earth rotates on its axis from west to east. (See Appendix).

13. Explain the terms Celestial Sphere, Celestial Poles, and Celestial Equator.

The Celestial Sphere is that unlimited, hollow vault of the sky, which we see above us, and to which the stars seem to be attached, like specks of gilding upon the inner surface of a dome.

If the axis of the earth be produced both ways to an infinitely great distance, it will cut the celestial sphere in two points, exactly opposite to each other. Around these two points the apparent motions of the heavens are performed, and they are therefore called the Celestial Poles; the one facing the north pole of the earth is called the North Celestial Pole, the other the South Celestial Pole.

The Celestial Equator is a great circle of the celestial sphere, drawn half way between the poles (therefore everywhere 90° from each of them), and is the great circle in which the plane of the earth's equator cuts the celestial sphere. It is often called the "Equinoctial."

14. Define the terms Zenith and Nadir.

If the direction of a plumb-line (that is, a slender thread with a heavy ball attached at one end) be imagined to be extended upward to the sky, it will meet the celestial sphere in a point directly overhead. This point is called the *astronomical zenith*, or simply *the zenith*.

The *nadir* is the point opposite to the zenith in the invisible part of the celestial sphere directly underneath.

15. What is the Celestial Meridian? What are the Cardinal Points? How many are they? Name them.

The Celestial Meridian is the great circle which passes through the zenith and the poles.

The points where the celestial meridian cuts the horizon are the north and south points, and half way between these two on either side are the east and west points respectively. All these four are called the Cardinal Points.

16. Explain in general how to find the equinoctial line of the heavens from any place on the earth's surface.

The equinoctial line of the heavens is everywhere equidistant, *i.e.* 90°, from either pole. Hence, it passes through the east point of the observer's horizon, crosses his meridian as many degrees *north* or *south* of his zenith as he is *south* or *north* of the terrestrial equator, and then passes through the west point of his horizon.

For example, with regard to Bombay, the equinoctial line passes through the east point of the horizon, crosses the meridian 19° south of the zenith (because Bombay is 19° north of the equator), and then passes through the west point of the horizon.

On a clear night the equinoctial line can be easily traced across the sky by following the course of the middle star of Orion's belt from rising to setting.

17. Explain the terms Ecliptic, Plane of the Ecliptic, and Plane of the Equator. Are these two planes one and the same? If not, what is the relation between them, and what physical phenomena are due to that relation?

If the plane of the earth's orbit be produced infinitely, it will cut the celestial sphere in a *great circle*, known as the Ecliptic, and so called because, as was early discovered, *eclipses* happen only when the moon is crossing this circle.

Note.—The ecliptic must not be confounded with the orbit of the earth, which only lies wholly within it somewhere.

The Plane of the Ecliptic is the plane in which the ecliptic, and consequently the earth's orbit, wholly lie.

Similarly, the Plane of the Equator is the plane in which the equator, terrestrial as well as celestial, wholly lies.

These two planes are not one and the same. They are inclined to each other at an angle* of about 23½°, and cut each other only at two opposite points, which are called the 'equinoxes' or 'equinoctial points.' To this inclination of the two planes to each other we owe the inequality in our days and nights, as also the four seasons of our year.

18. **Explain clearly why, as a rule, the days and nights are unequal, and shew that in two positions of the earth's orbit the days and nights are equal all over the globe, and that at the equator they are equal throughout the year.**

To understand the causes of the inequality of days and nights, four important facts concerning the earth must be borne in mind. First, that the earth is not stationary, but revolves round the sun in a year's time. Secondly, that the plane of the ecliptic is inclined to the plane of the equator at an angle of 23½°. In other words, the axis of the earth is not vertical, but inclined to the vertical at 23½°. Thirdly, that the north pole always points very nearly to the same point in the heavens, *viz.* the North Celestial Pole, close to which is the star known as the Pole-star. In other words, the axis is parallel to itself in whatever part of its orbit the earth may be. And fourthly, that the sun can illumine only one-half of the globe at any time, neither more nor less.

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* The angle between the two planes is constant all the year round and is termed the Obliquity of the Ecliptic.

Form a consideration of these four facts we come to the conclusion that the north pole is at one time turned *away from* the sun, at another time *towards* it; but that at two other times it points neither *away from* nor *towards* the luminary. In the last two cases, the *Terminator*, or the circle which bounds the illuminated portion of the earth, passes through both the poles, so that on these days every place on the earth's surface takes as much time to pass through the lighted half as through the dark half; hence equal day and night all over the globe (21st of March and 21st of September). In the other two cases, the terminator does not pass through either pole, so that every place takes more or less time, as the case may be, to pass through the lighted half than through the dark half. Hence the inequality of day and night.

At the equator, however, the day and night are *always of equal length*, because the terminator always divides the equator into two equal parts. (Fig. 4.)

19. Explain the phenomena of the seasons; Or, Explain how the seasons depend upon the difference in the lengths of day and night.

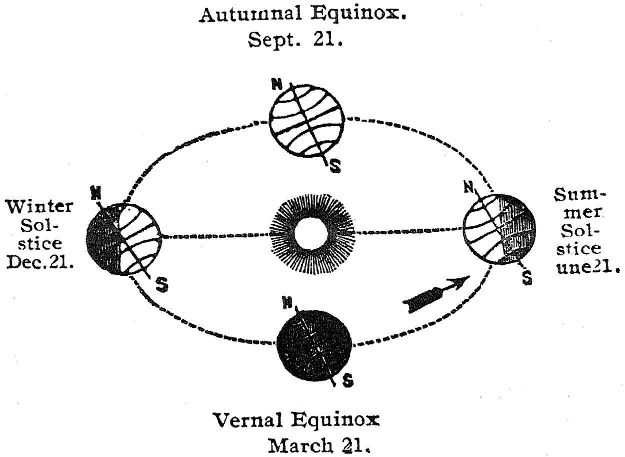

Fig. 4.—The Seasons. (Ques. 18 and 19).

The earth in its annual journey round the sun keeps its axis always nearly parallel to itself, for the mechanical reason that a body rapidly rotating about an axis has a tendency to preserve the direction of that axis, unless disturbed by extraneous forces.

About the 21st of December, the earth is so situated that its south pole is inclined towards the sun by about $23\frac{1}{2}^\circ$. The north pole then never sees the light of the sun, while the south pole receives sunlight all day long; and in all portions of the northern hemisphere the day is shorter than the night, the difference depending upon the latitude of the place; in the southern hemisphere, on the other hand, the days are longer than the nights. And it is evident that short days and long nights would produce great cold; and long days and short nights great heat. Add to this that at this time of the year the sun's rays fall at a very great slant upon the northern hemisphere and have to pass through a thick layer of atmosphere which absorbs much of the heat, so that only a small amount is allowed to reach the earth's surface. Thus this is the time of winter in the northern hemisphere, and summer in the southern.

About the 21st of June, these conditions are reversed, and the northern hemisphere has summer, the southern has winter.

About the 21st of March and of September, the earth is so situated that the plane of its equator passes through the sun. At that time, therefore, the terminator passes through the two poles, and day and night are everywhere equal, as implied by the term 'equinox.' And as equal days and nights would produce neither great cold nor great heat, these are the times of spring and autumn respectively.

At the equator, however, the day and night are always equal, so that in that part of the earth there are no seasons in the proper sense of the word. (Fig. 4).

20. If the plane of the ecliptic coincided with the plane of the equator, how would the phenomena of day and night and of the seasons be affected? Or,

What changes would be produced on the earth if its axis were to place itself at right angles to the plane of the ecliptic?

If the axis of the earth were to place itself at right angles to the plane of the ecliptic, then the two planes of the equator and the ecliptic would coincide, the rays of the sun would always be perpendicular to the equator, the line between light and darkness would always pass through the poles, and all over the earth the sun would cross one particular path in the sky, attaining the same noon-day elevation throughout the year for the same place, though different for different latitudes. As a result of all this, the day and night would always and everywhere be equal, and in consequence of that there would be nothing like the four seasons of the year.

21. In what parts of the earth is the sun never right overhead, and why? How often in a year is the sun vertical at Bombay?

The sun's rays can fall perpendicularly upon the earth's surface only between the tropics. Beyond that they are never perpendicular, not even during the heat of summer. This is because the earth's axis is inclined to the perpendicular to the plane of its orbit at an angle of 23½° and always remains parallel to itself, so that the straight line joining the centre of the earth with the sun always cuts the globe within 23½° north or south of the equator, which limits are hence called the *torpics*.

Since Bombay is in 19° North Lat., the sun is overhead twice a year, about June 5, when it passes from the south to the north, and about the same day of July when it re-crosses from north to south.

22. What facts go to prove that the earth travels round the sun once in a year ?

The annual journey of the earth round the sun has been proved from the apparent motions of the sun round the earth.

(1). The sun has an apparent motion *eastward* among the stars which makes it describe the circuit of the heavens once in a year. In spring the stars, which at sunset are rising in the eastern horizon, are different from those which are found there in summer or winter.

(2). As seen by us in Bombay, the sun, starting on the 21st of March, mounts higher in the sky each day at noon for three months, appears to stand still for a few days at the summer solstice (June 21), and then descends towards the south, reaching on the 21st September the same noon-day elevation which it had in March. It keeps on its southward course to the winter solstice (December 21), and then returns to its original height at the end of a year on the 21st of March.

Now these two movements of the sun can be explained by supposing either the earth to revolve round the sun, or the sun round the earth. The former supposition is more consonant with reason, for,

(1). The great size of the sun compared with that of the earth renders it easier to suppose the latter moving round the former than the contrary; and,

(2). Comparing the distance of the earth from the sun, and the period of the sun's apparent revolution round the earth, with the distances and periods of the planets which revolve round the sun, it seems probable that the earth is a planet, and is subject to the same laws of motion as the others.

But these are mere arguments, no proofs. That the earth really moves, is absolutely demonstrated by two phenomena too minute and delicate for observation without the telescope. One of them is the *aberration of light*,* the other the *annual parallax of the fixed stars*.‡ These can be explained only by the actual motion of the earth.

23. What is the shape of the earth's path round the sun? How is that shape determined?

The orbit of the earth, or its path round the sun, is not a circle but an ellipse. It is determined from a comparison of the daily measurements of the sun's apparent diameter which gradually increases from July to January and then decreases from January to July. If the earth's path were a circle the sun's diameter would always appear of the same size. These variations, therefore, clearly prove an elliptical orbit with the sun in one of the foci. (See Ques. 97).

24. Is the earth's motion in its orbit a uniform one? If not, why not?

The earth's orbital motion is not uniform, because the orbit is not a circle. It moves fastest when it is at perihelion† or nearest to the sun, and slowest when it is at aphelion* or farthest away from it. Between these points its speed varies with its distance from the sun. This is in accordance with the Second Law of Kepler,† which requires a planet to move faster, the nearer it is to the sun, in order to overcome the greater centripetal force at that time.

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* See Appendix. ‡See Ques. 164. † See Ques. 99.

25. The sun is about three million miles nearer the earth in winter than in summer; how, then, is the greater heat of summer to be accounted for ?

In the first place, the statement that "the sun is nearer to the earth in winter than in summer" is not true of the whole world, but only of the northern hemisphere. Secondly, it must be remembered that winter and summer are caused, not by the nearness or remoteness of the sun, but by the varying position of the earth's axis in different parts of its orbit, by the consequent inequality in the lengths of day and night, and by the verticalness or slant of the sun's rays.

26. What is the length of the period in which the earth finishes one revolution round the sun ?

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* See Ques. 99. † See Appendix.

The period in which the earth finishes one revolution round the sun is commonly called a *year*. When reckoned with regard to the return of either of its poles to the depths of winter, it is 365 days, 5 hours, 48 min., 49·75 sec. long, and is called a *tropical year*. When reckoned with regard to its return between the sun and the same star, its length is 365 days, 6 hours, 9 min., 9·6 sec., and it is called a *sidereal year*. The difference is due to the fact that the earth wabbles a little when rotating on its axis, just as a top does when it begins to lose the force of its first perpendicular spinning. In other words, its axis does not always keep the same precise direction, though it is *almost* parallel to itself.

27. Explain clearly why noon at Madras is half an hour earlier than at Bombay.

As the earth rotates on its axis *from west to east*, the sun seems to approach from the east, and rises earlier at any one place than at another place further west. Again, since the earth finishes one rotation in about 24 hours, every place on its surface is carried in that time through four right angles or 360°. This gives 15° of longitude for one hour of time. Now, as Madras is about 7½° east of Bombay, the sun rises half an hour earlier there than with us. Consequently, noon at Madras is also earlier than at Bombay by half an hour.

28. A person travels from Bombay to Calcutta; state, giving clear reasons for your answer, whether his watch will appear to have gained or lost on his arrival at his journey's end.

As Calcutta is to the east of Bombay, the sun rises at the former place earlier than at the latter, in consequence of the earth's rotation on its axis from west to east. Thus Bombay time is about an hour behind Calcutta time. Hence, if a man leaves Bombay for Calcutta with a watch set according to Bombay time, he will find that it has apparently *lost* when he comes to his journey's end.

29. Explain the apparent paradox contained in the following statement:—"A telegram which left Bombay this morning was delivered in London yesterday evening."

As Bombay is about 72° east of London, the sun rises here about five hours earlier than it does at London, in consequence of the earth's rotation on its axis from west to east in 24 hours. Thus Bombay time is about 5 hours in advance of London time. Hence if a telegraphic message leave Bombay at 1 *a.m.* and if we allow two hours for transit, it will be delivered in London at 3 *a.m.* of Bombay time, *i.e.* at 10 *p.m.* London time of the preceding day.

30. If a steamer, sailing due west at a uniform rate, circumnavigates the earth in 60 days, what will be the interval of time between any two successive noons on board the ship ?

If in 60 days it passes through 360° of longitude,
∴ in 1 day ,, 6° ,,
That is to say, each day it will be 6° more to the west than it was on the preceding day; so that the sun will be each day later in gaining the same point in the heavens by 24 minutes. (15° : 6° :: 1 hr. : x. $x = \frac{2}{5}$ of 1 hr. = 24′.). Therefore the interval of time between any two successive noons on board the ship will be 24 hrs. 24 minutes.

31. In the last question, what difference would it make if the steamer were proceeding due east instead of west at the same rate ?

In this case the steamer would, as it were, go *to meet* the sun every morning instead of running away from him as it did in the last question. Consequently, the sun would gain the same point in the heavens in 24 minutes *less* than 24 hours. Thus the interval of time between two successive noons would be 23hrs. 36 minutes.

32. The captain of a ship at sea finds the local time to be 12 o'clock noon, when his chronometer regulated by Greenwich time marks 6-30 p.m. What is the longitude of the ship's place ?

The difference between the two times is $6\frac{1}{2}$ hrs.,

$\therefore$ The difference in longitude is $15 \times 6\frac{1}{2}$, *i.e.*, $97\frac{1}{2}$ degrees. (1 hr.: $6\frac{1}{2}$ hrs. $:: 15^\circ : x$).

Now, as the local time is *behind* Greenwich time, the place must be *west* of Greenwich:

$\therefore$ Longitude of the ship's place is $97\frac{1}{2}^\circ$ W.

33. An Eclipse of one of Jupiter's moons took place at 11 a.m. at Greenwich, the phenomenon being observed at another town at 2 p.m. of its local time. Find the longitude of the latter place.

The difference between the two times is 3 hrs.

$\therefore$ The difference in longitude is 15×3, *i.e*, 45°. (1 hr.: 3 hrs $::$ $15^\circ : x$).

Now, as the local time is *in advance of* Greenwich time, the town must be *east* of Greenwich.

$\therefore$ Longitude of the town is 45° E.

34. The Time Ball over the Clock Tower at the Bombay Castle continues to drop regularly at 1 p.m. of Colaba mean time, or at 8h. 8m. 44·3s. a. m. Greenwich mean time. Determine the longitude of Bombay.

Ans. 72° 48′ 55″·49 E.

35. The Ball drops at Prince's Dock at 7h 51m. 15.7s. corresponding to exactly 3hrs. a.m. Greenwich mean time. What is the longitude of the Dock ?

36. Why do ships crossing the meridian 180° add a day to their reckoning or subtract one from it ?

When it is midday at Geenwhich it is midnight at places on meridian 180°. Now these places may be considered to be 12 hours before Greenwich time or 12 hours behind it, according as they are reckoned in 180° E. or 180° W. longitude. Hence, if a ship sail from London westward by America, on reaching meridian 180° the chronometer on board the ship will appear to have lost 12 hours, whereas in sailing east by the Suez Canal 12 hours will be apparently gained. This difference, *in sailing round the world*, will in each case amount to 24 hours. In the first case, if it is Sunday on board the ship when it returns to dock, it will be Monday in

London; in the second case the Sunday of the voyagers is Saturday in London. This difference in the calendar is remedied by adding a day on reaching meridian 180° if the ship is sailing westward, or by dropping a day if it sails eastward.

Note:—The teacher will explain this paragraph with the help of a map of the globe before the class.

37. Give the approximate length of the Earth's equator, and hence calculate how many miles an hour a man at the equator must be travelling owing to the earth's rotation on its axis.

The length of the equator is about 25,000 miles; so that a man at the equator is carried through 25,000 miles in the 24 hours of the earth's rotation. Hence, in one hour he is carried through the 24th part of 25,000 miles, *i.e.*, a little more than a thousand miles.

38. Give (a) the exact length of the Earth's equatorial diameter; (b) the exact length of its polar diameter; (c) the exact time in which the earth completes one rotation on its axis; (d) the exact time in which it completes one revolution round the sun.

(*a*). 7925½ miles.

(*b*). 7899 miles.

(*c*). 23 hours, 56 minutes, and 4·1 seconds.

This interval of time is called a *sidereal day* because it is measured off by the stars appearing to return into the same position in the sky.

(*d*). 365 days, 6 hours, 9 minutes, and 9·6 seconds. This is called a *sidereal year.*

39. What are the Solstices? How many are they? And why are they called so?

Careful observation of the sun's daily path in the visible hemisphere of the sky shows that it describes arcs of continually increasing size from winter to summer, and of continually diminishing size from summer to winter. About June 20, the noon-day sun is 23½° higher than about March 20. For a few days it appears to describe the same arc in the sky and no change is perceptible in its midday altitude. This point is called the Summer Solstice, because the sun appears to stand still (L. *sol*, the sun, and *sto*, I stand).

Again, about Dec. 21, the sun at noon is 23½° lower than on the same day of March or September, and appears to stand still once more for some days. This point is called the Winter Solstice.

Thus the difference between the noon-day elevations of the sun at the two solstices is about 47°.

40. Distinguish clearly between the Sidereal day and the Natural or Solar day.

The Sidereal day is the interval of time which the earth takes to complete one turn on its axis and to return to the same position *with reference to a fixed star*. (L. *Sidus*, a star). Its length is 23h. 56′ 4″·1.

The Natural or Solar day is the interval of time which the earth takes to return to the same position *with reference to the sun*. Its length is 24 hours on an average. It is longer than the sidereal day because the Earth, while twisting upon its axis, is also *moving on* in its circular path about the sun.

Figure 5 shows how any place on the earth's surface requires more time to regain the same position with regard to the sun than with regard to a fixed star.

Again, the sidereal day is always of the same length, because the earth's rotation is the *most regular and uniform* occurrence that we know of. Whereas the solar day is not always of one length, some solar days being nearly half an hour longer than others. This is because the Earth *moves quicker* in some parts of its orbit than it does in others. (See Ques. 24.)

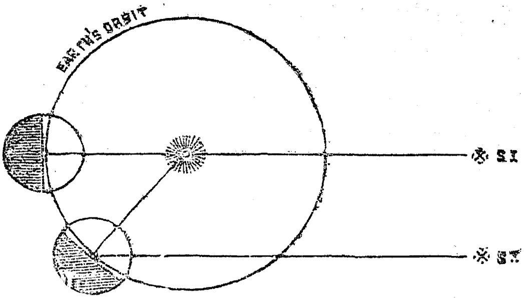

Fig. 5.—The Sidereal and the Natural or Solar Day

41. Of how many apparent movements of the Sun do you know? Explain briefly the causes producing them.

We know of four apparent movements of the Sun, caused by some real movement of our Earth.

The first is the daily movement of the sun in the heavens from east to west, to be accounted for by the Earth's rotating on its axis from west to east.

The second is the Sun's continual shifting of rising-place between the north-east and south-east. On the 21st of March (Vernal Equinox) the sun rises due east of every place on the earth's surface. From that day, he rises more and more towards the north, till on the 21st of June (Summer Solstice) he has reached the utmost north-eastern point. Then he begins to return and in three months more, on the 21st of September (Autumnal Equinox), he has regained the due east.

From this day he rises more and more towards the south, until he gains the utmost south-eastern point on the 21st of December (Winter Solstice), when he turns back and reaches the due east again on the 21st of March. This second apparent movement of the sun is due to the Earth's revolving round him in a year.

The third apparent movement is the Sun's moving from north to south along the meridian of a place in the course of a year. This is in consequence of the second apparent movement explained above.

The fourth and last apparent movement of the Sun is his change of place month after month among the fixed stars. Beginning on 21st March with the Constellation Aries (*the Ram*), he *seems* to move gradually backwards, or to lose, as it were, among what are called the 12 Zodiacal Constellations, passing through each of them in a month's time and returning to the same place at the end of a year. This apparent movement is likewise due to the Earth's revolving round the Sun.

43. How many apparent motions do you know of the fixed stars? To what causes are they due?

The fixed stars have four apparent motions in the heavens:—

(1) A daily motion from east to west, caused by the diurnal rotation of the earth from west to east.

(2) A forward movement towards the west, by which a star rises every day earlier than it did the previous day, thus seeming to complete one revolution of the heavens in a year. This is due to the revolution of the earth round the sun.

(3) An exceedingly slow movement round the poles of the ecliptic, completing a revolution in 26,000 years, due to the Precession of the Equinoxes. (See Appendix.)

(4) A closing-up of the stars in one part of the heavens, and an opening-out in the opposite part, just like the apparent closing-up or opening-out of a grove of trees as a traveller recedes from it or approaches it. This apparent motion is caused by the real motion of the earth along with the sun and other members of the solar system towards the Constellation Hercules. (See Ques. 11.)

44. Shew, in general, that the Altitude of the Pole (i. e., its height in degrees above the horizon of a place) is always equal to the Latitude of the observer. What is the practical use of this fact?

Since the axis of the earth is always directed to the same points in the heavens, *viz.* the North and South Celestial Poles, in whatever part of its orbit the earth may be, it follows that when an observer is at the N. P. (or S. P.) of the earth, *i.e.* in lat. 90°, the N. P. (or S. P.) of the heavens is at his zenith, *i.e.* 90° above his horizon; when he is at the equator, *i.e.* in lat. 0°, both poles of the heavens are on his horizon, *i.e.* in altitude 0°. Thus, as he travels along the same meridian from either pole to the equator through 90° of latitude, the pole also descends through 90° of altitude. Hence, for any intermediate place, the pole stands as many degrees above the horizon as the observer is away from the equator on either side. In other words, the altitude of the pole is always equal to the latitude of the observer.

A knowledge of this fact is very useful to travellers on sea and land to determine in what latitude they are, but only at night-time and in the northern hemisphere, for there only is the Pole-star to mark the position of the N. P. of the heavens, there being no star in the South Celestial Sphere near enough to mark the position of the S. P. of the heavens.

45. Describe the apparent motions of the heavens as seen by a person from the North Pole.

A person at the N. P. of the earth, if he watch the stars for only a few hours of the night, will find that, while all their configurations remain unchanged, their places in the sky are slowly changing. He will find a particular star nearly overhead, whatever be the season of the year. This is the Pole-star.* The other stars will all appear to be moving in concentric circles around a point near the Pole-star, in direction contrary to that of the hands of a clock, *i.e.*, from right to left. Each star will return to its original place after 24 hours nearly. None of them will ever be seen to sink below the horizon, nor will any new star ever rise above the horizon.

46. Describe the apparent motions of the starry heavens as seen from the S. P.

The movements of the stars seen from the S. P. of the earth are precisely similar to those at the N. P., with the only difference that they revolve in the same direction as the hands of a clock, *i.e.* from left to right. Also, there is no star close enough to the South Celestial

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*The student must be careful not to confound the Pole with the Pole-star. The pole ia an *imaginary point*; the pole-star is only the nearest star that is seen with the naked eye. The distance between the two is, at present, about $1\frac{1}{4}°$.

Pole which can be called the South Pole-star, just as the star near the North Celestial Pole is called the (North) Pole-star.

47. Describe the apparent motions of the heavens as seen from a point on the equator.

A person at the equator (that is. in lat. *zero*) would every night expect to see the Pole-star just on his northern horizon, provided there be no rising ground or any other object to obstruct his view in that direction. Of the other stars, those that rise due east will travel in a vertical line, pass right over his head and set due west. Those that do not rise due east, but nearer the north or the south, will describe semi-circles parallel to the vertical from east to west, and will set as many degrees away from the west as they rose from the east. They will remain 12 hours above the horizont and 12 hours below it, and the day and nigh will always be equal in length. This aspect of the heavens is called the *Right Sphere*.

But the same stars will not always be found in the same place at the same hour. Some new stars will be every day coming into view, some old ones will be every day disappearing, and the whole procession will regain its original place only after a year.

The equator, therefore, is the only place on the earth's surface from which all the stars in the heavens are successively exposed to view in a year's time.

48. Describe the apparent motions of the starry heavens as seen by an observer in London.

To a person in London the Pole-star always appears in the meridian line of his sky, about 52° above the north point of the horizon (because London is in 52° North Latitude—see Ques. 44) and therefore about 38° to the north of his zenith. Of the other stars, those that are within 52° of the Pole-star never sink below the horizon, but move in concentric circles round it from right to left, *i.e.*, in the direction opposite to that of the hands of a clock. These are, therefore, called the constellations of "perpetual apparition,"* or "circumpolar constellations." The remaining stars, which are seen to rise and set once every day, describe arcs of circles (called the stars' *diurnal circles*) parallel to those along which the circumpolar stars are travelling. These stars change with the season, owing to the revolution of the earth round the sun.

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*The constellations of perpetual apparition in the latitude of London are—the Great Bear (L. Ursa Major; also called the Plough, or Charles' Wain), the Little Bear (L. Ursa Minor), Cassiopeia, Cepheus, the Dragon, the Camelopard, Perseus, and Auriga.

49. Describe the apparent motions of the starry heavens as seen by us in Bombay.

(Repeat the answer to the last question, changing 52° into 19°, 38° into 71°, and adding the following note:—

There are very few stars visible to the naked eye within 19° of the Pole-star, and consequently very few circumpolar constellations observable in Bombay.)

50. Describe the apparent movements of the starry heavens as seen by an observer in Australia.

Australia lies between 15° and 40° south of the Equator. Let us suppose our observer to be at Melbourne in Victoria, 38° South Latitude. Then, as he looks up on a clear night towards the south, he will see a number of stars moving slowly in circles round a point 38° above the Southern Horizon. But the movement will be, not from right to left as seen in England or in India, but from left to right, *i.e.*, in the same direction as that of the hands of a watch. These are the Southern Circumpolar Stars of "perpetual apparition." The other stars that rise and set will describe circular arcs parallel to the paths of the circumpolar stars.

None of the stars, however, will be seen to keep the same position at the same hour on successive nights. Every star will appear a little more to the west any one night than it was the preceding night at the same hour, and will not regain the same place at the same hour till after a year.

51. Why do the fixed stars appear to move differently in different parts of the earth? Describe the changes that a man would observe in their movements when travelling from the North Pole to the equator along the same meridian.

The fixed stars appear to move differently in different parts of the earth, because the earth is a spherical body rotating upon its axis, the extremities of which always point to nearly the same points in the heavens.

A man at the N. P. of the earth always has the Pole-star right overhead, and the other stars move in circular paths round this star; they never sink below the horizon, nor do any new stars ever come above the horizon. (See Ques. 45). As he leaves the N. P. and travels southward, for every degree he moves, the Pole-star falls one degree to the north point of the horizon. Thus, when he comes to the latitude of London (52°), the Pole-star has fallen 38° (90° – 52°) below his zenith to the north, being 52° above the north cardinal point. (See Ques. 44). Of the other stars, those that are within 52° of the Pole-star describe circular paths entirely above the horizon, and are therefore called "Constellations of Perpetual Apparition." The remaining stars rise and set once in a day and change with the season. (See Ques. 48). A similar appearance is presented at any other latitude north of the equator. At the equator, the Pole-star nearly ceases to be seen, being just at the north ponit of the horizon ; and all other stars describe semi-circles parallel to the arc joining the east and west through the zenith. (See Ques . 47).

Note.—The equator is the only place on the earth's surface at which *all the stars in the heavens* successively come in sight of an observer in the course of a year.

THE MOON.

52. In what relation does the moon stand to the earth?

The moon is the constant companion or attendant of the earth in its long journey round the sun, and is subjected to the force of gravitation from the earth, just as the earth is from the sun. It is, therefore, called the Satellite of the earth.

53. What is the nature of the path described by the moon round the earth?

In accordance with the First Law of Kepler (see Appendix), the moon moves in an elliptical path round the earth ; but, as the earth is moving round the sun at the same time, the moon practically describes a very irregular wave-like curve in space. (See note on Ques. 88.)

54. How far distant is the moon from the earth? What is the length of the moon's diameter?

The moon is not always at the same distance from the earth, owing to the ellipticity of its orbit ; the mean distance is about 240,000 miles. The greatest distance is 251,700 miles.

Note.—The point of the moon's orbit nearest the earth is called *perigee*, that most remote is called *apogee.* (See Ques. 99).

The diameter of the moon is about 2,000 miles in length, or one-fourth of the diameter of the earth.

55. What are the Phases of the Moon? Explain them with the help of a diagram, and describe an experiment to illustrate them.

The Phases of the Moon are the changes in form that the moon runs through in the course of a month as seen by the inhabitants of the earth. *Really*, the moon does not change.

The moon is a dark globular body revolving round the earth as the earth does round the sun. The rays of the sun fall upon the moon as they do upon the earth, and always illumine the half facing it. We do not, however, always see this fully illumined disc, but only such portions of it as are turned towards us, depending upon the relative situations of the earth and the moon. Accordingly, we have the following phases in the course of a lunar month of about 29½ days:—

(*a*) When the moon is in a line between the earth and the sun, the dark side is turned entirely towards us, and the moon is invisible. This is "No Moon."

(*b*) A day or two later, when the moon gets a little away from the line joining the earth and the sun, we just see a fine edge of its illumined half, and call it "New Moon."

(*c*) For a week the edge goes on increasing and takes the shape of a "Crescent."

(*d*) At the end of a week from the No Moon, exactly half of the illumined disc is seen, and is called "Half Moon" or " First Quarter."

(*e*) The half continues to increase for a week, during which period it is termed "Gibbous."*

(*f*) At the end of the second week from the No Moon, we see the whole of the illumined disc and call it "Full Moon."

(*g*) After the Full Moon the illumined disc gradually diminishes, becoming first Gibbous then half (called "Last Quarter"), then crescent, and finally altogether disappearing.

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* " Gibbous " means crooked-backed or bunched out. One side of the Gibbous moon is more bunched out than the other.

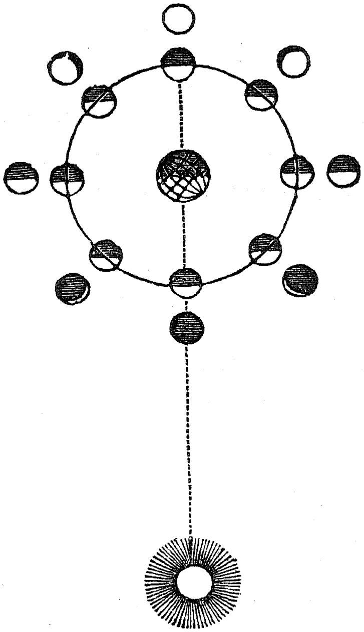

Fig. 8.—Phases of the Moon.

Experimental proof:—Paint an ordinary ball half black and half white, and fix a pin in the centre of the white half. Stand before a lamp (not necessarily lighted) placed on a table, holding the ball fixed vertically on a needle so that the pin in it faces the lamp. Notice that you see only the dark side of the ball. Then slowly turn round on your axis, at the same time twisting the needle so that the pin in the ball still faces the lamp. Observe that a thin line of the white side becomes first visible and then goes on increasing until you see half of the white when you have moved a quarter of a circle round on your axis. Continue the movements until you see the whole of the white side before you when your back is just turned to the lamp. Move on in the same way, and the white side will get more and more out of sight till you are once more facing the lamp with the dark half of the ball entirely turned towards you. This is precisely what happens with the moon.

56. What appearance would the Earth present to a spectator on the Moon's surface?

"The man in the moon," as he is humorously called,—if such a one be there—would not always be able to see the Earth, nor always of the same shape when he can. As the moon always presents the same face to the earth (Ques. 86), an observer on that face would always have the earth before him, though he cannot always see it, owing to its being buried at times in the sun's dazzling light.

For him the earth would pass through all the same phases that the moon passes through for us. He would have a New Earth, gradually passing through the Crescent, the Half, and the Gibbous, to the Full Earth, and back again in the reverse order to the New Earth; the only difference being that during the period that we have the moon waxing from New Moon to Full Moon, he would see the Earth waning from Full Earth to New Earth, and *vice versa*. Again, the full earth would appear to him as a flat, circular plate of great brilliancy, being 13 times as large as what the full moon appears to us.

57. Explain the following terms as applied to the moon.—Elongation, Conjunction, Opposition, Quadrature.

Elongation is the angular distance of the moon east or west of the sun at any time.

The moon is said to be in *Conjunction*, when it is in a line between the earth and the sun, *i.e.* at New Moon. The elongation then is 0°.

The moon is said to be in *Opposition*, when it is in a line with the earth and the sun, but on the side of the earth opposite to the sun, *i.e.* at Full Moon. The elongation then is 180°.

The moon is said to be in *Quadrature*, when the straight lines drawn from the moon and the sun to the earth meet at right angles. This happens at half moon. The elongation then is 90°.

At Conjunction the moon rises and sets with the sun. At Opposition it rises at sunset and sets at sunrise. At Quadrature it is either rising or setting when the sun is on the meridian.

58. What is an Eclipse?

The term *eclipse*, from a Greek word meaning "a disappearance," denotes a phenomenon inwhich a heavenly body is shut out from view by the interposition of another body.

59. How is an eclipse of the sun caused?

An eclipse of the sun occurs when the moon travelling in its orbit comes between the sun and the earth so as to cut off all the light-rays coming from the former to the latter.

60. How is an eclipse of the moon caused?

A lunar eclipse, or an eclipse of the moon, is due to the interposition of the earth between the sun and the moon. The sun is at night under our feet at the other side of the earth, and the earth throws a long shadow upwards. If the moon enters into this shadow, it is plain that the sun-light is partly or wholly cut off; and, since the moon shines by no light of its own, but only by light borrowed from the sun, it follows that, when the moon is buried in the shadow, all the direct light is intercepted, and it must lose its brilliancy.

61. Why is it that an eclipse of the sun can take place only at new moon, and an eclipse of the moon only at full moon?

A solar eclipse is due to the interposition of the moon between the earth and the sun; at this time the moon's dark side is necessarily turned towards us, that is, it is new moon.

A lunar eclipse is due to the interposition o the earth between the sun and the moon; at this time the moon's illuminated side is necessarilly turned towards us, that is, it is full moon.

62 Why do there not occur one solar and one lunar eclipse every month?

We would have two eclipses every month, one solar and one lunar, if the orbit of the moon were in the plane of the ecliptic. As it is, however, the moon's orbit is inclined to the plane of the ecliptic at an angle of 5°, and cuts the ecliptic only at two opposite points called the *nodes*. The result is that the moon, when in a line with the sun and the earth, is often a little higher or a little lower than the plane of the ecliptic, thus avoiding an eclipse either of the sun or of itself.

63. Name and explain the different kinds of solar eclipses.

An eclipse of the sun may be one of three kinds ;—it may be *total*, when the entire disc (or photosphere) is concealed from view; *partial*, when part only of the disc is concealed from view; and *annular*, when the disc is so concealed from view as to leave a ring round the edge of the sun visible.

64. Why is it that we have sometimes a total, sometimes a partial, and sometimes an annular, eclipse of the sun ?

As the moon moves round the earth in an elliptical orbit, it is at one time nearer to us than at another. Hence, if a solar eclipse happens with the moon nearest to the earth, the whole of the sun's disc will be covered by the moon, and we shall have a total eclipse. If, however, the moon be so far away from us at the time of a solar eclipse that its disc, diminished by distance, is not large enough to cover the whole of the sun's disc, we shall have only an annular eclipse.

But the total or the annular eclipse occurs only when the moon is at one of its nodes, *i. e.*, when the sun, the moon and the earth are in one *straight* line. But if the moon happen to be a little above or below the line joining the earth and the sun, the sun will be covered only in part, and that is called a partial eclipse.

65. Draw diagrams to illustrate a total and an annular eclipse of the sun.

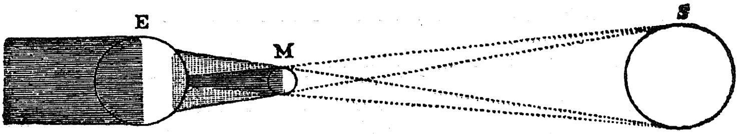

Fig. 9.—Total Eclipse of the Sun.

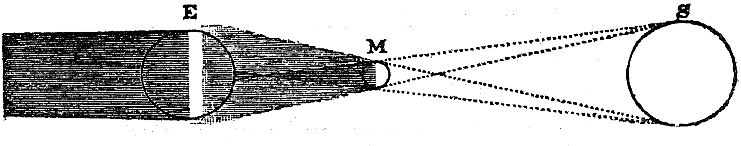

Fig. 10.—Annular Eclipse of the Sun

66. Name and explain the different kinds of lunar eclipses. Draw a diagram showing a total eclipse of the moon.

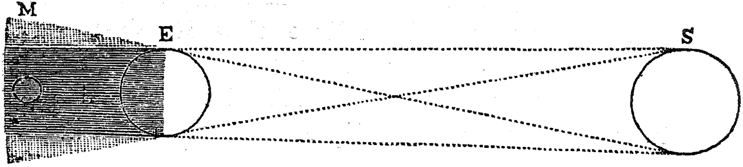

Fig. 11.—Total Eclipse of the Moon.

Lunar eclipses are of two kinds,—total and partial; total, when the moon is completely buried in the shadow of the earth; partial, when it goes so far above or below the centre of the shadow as to have a portion only of its disc obscured.

67. Why can there not be an annular eclipse of the moon like that of the sun?

An eclipse of the sun is annular when the apparent diameter of the sun as seen from the earth is greater than that of the moon. Similarly, in order that a lunar eclipse may be annular, the *actual* diameter of the moon must be greater than the diameter of the earth's shadow at the place where the moon crosses it. This is impossible, since the width of the earth's shadow at that place is over 5,000 miles, whereas the *actual* diameter of the moon is only 2,000 miles. Hence a lunar eclipse can never be annular.

68. What conditions must concur to produce a total solar eclipse?

To produce a total solar eclipse, the moon must be (1) in conjunction with the sun as seen from the earth (*i.e.* it must be "No Moon," erroneously called "New Moon"); (2) exactly at one of its nodes; and (3) in perigee, if possible; if not, at least so close to the earth as to have its apparent diameter greater than, or equal to, the apparent diameter of the sun at the time.

69. What conditions must concur to produce a lunar eclipse?

That a lunar eclipse may happen, the moon must be (1) in opposition (*i.e.* it must be Full Moon); (2) at, or very near to, one of its nodes.

70. Why do solar eclipses begin only on the western limb, and lunar on the eastern?

Like all other planetary bodies the moon revolves round the earth *from west to east.* Therefore eclipses of the sun are always seen to begin on the western edge of the sun and to move towards the eastern, and those of the moon begin on the eastern limb of the moon and end on the western.

71. Describe the phenomena seen during a total eclipse of the sun.

When a total eclipse of the sun is about to occur, the sun's face is slowly obscured until only a crescent of light is left. Stars make their appearance one by one; in a few moments total darkness prevails; the lunar disc is surrounded by a halo or corona; and red flames, called prominences, are seen shooting out thousands of miles high into the corona. On earth, beasts and birds are frightened by the unusual sight into their caves and nests; all nature prepares for the repose of night. Suddenly the darkness disappears, the fright gradually ceases, nature wakes up again, and in a few minutes more all is tranquil as before.

72. Describe the appearance of the lunar disc during the interval when the solar or lunar eclipse is total.

During a total solar eclipse we have the dark side of the moon turned towards us, and can consequently distinguish nothing on its surface.

During a total lunar eclipse[*] one might naturally expect the moon to become totally invisible; yet it is a curious fact that it is often distinctly visible though buried in the depth of the earth's shadow. It then glows with a dull copper-coloured light, which is bright enough to render some of the chief marks on its surface discernible. This is owing to the sun's light being bent by the earth's atmosphere towards the moon, thus tinging it with a ruddy colour.

73. Of what astronomical importance is a total solar eclipse? Or,

What is the object of sending out an 'eclipse expedition'?

A total solar eclipse is of great astronomical importance in as much as it furnishes opportunities (1) for the search of other planets too near the sun to be seen at other times, (2) for telescopic and spectroscopic observations of the prominences and corona, and (3) for drawings and photographs of these objects. Also, the passage of the moon's edge before the brilliant light of the sun's face gives a ery favourable opportunity for a close examiation of the details of those portions of the unar surface.

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[*] In strict accordance with the definition of the term *eclipse* (see Ques. 58) the moon cannot be said to be eclipsed, since it is not *concealed* but only *darkened*.

74. Of what astronomical importance is an clipse of the moon ?

During a lunar eclipse the outline of the arth is cast upon the moon, and we are then nabled actually to see the shape of our lanet, which we can never see otherwise.

75. What is the duration of eclipses, solar nd lunar ?

A total eclipse of the sun, seen from the quator under the most favourable conditions ossible, lasts for nearly 8 minutes. In higher atitudes the time gets proportionately shorter.

An annular eclipse of the sun may continue isible at the equator for about 12 minutes.

A lunar eclipse, when *central*, *i. e.*, when he moon moves along the *diameter* of the arth's shadow, may continue total for about wo hours; when it passes above or below the diameter of the shadow, the duration is, of course, proportionately shortened.

76. Why are lunar eclipses seen from a reater portion of the earth's surface than lar eclipses ?

During a solar eclipse the shadow of the moon falls on a very small part only of the earth's surface, and only from this part can the eclipse be seen. During a lunar eclipse, however, the whole of the dark side of the earth has the moon before it, so that the eclipse will be visible from more than a hemisphere.

77. How many eclipses occur in a year? Which are more frequent, solar eclipses or lunar, and why?

The greatest number of eclipses in a year is seven, five solar and two lunar, or three solar and four lunar; the least number is two, both solar; the most usual number is four, two solar and two lunar. Thus a whole year may sometimes pass without a single eclipse of the moon.

Taking the whole earth into account, solar eclipses are the more frequent of the two, the ratio being nearly as 3:2. But *as regards any given place on the earth's surface*, a greater number of lunar eclipses is seen in a given time than solar. The reason is that a solar eclipse is only visible over a small portion of the earth's surface; whereas a lunar eclipse is visible over considerably more than half the earth. And this more than reverses the proportion of solar to lunar eclipses visible at a given place.

78. Is there any kind of regularity noticeable in the way in which eclipses occur ?

The eclipses of any one year are materially different from those of the years immediately preceding or following. But after 18 years and 10 days the same series of eclipses begins again, both as regards character, duration and interval of occurrence. During one such period there occur 41 solar and 29 lunar eclipses. The reason is that at the end of the period the moon's nodes are again in the same situation in its orbit, and the moon occupies the same place with regard to the sun and the earth.

79. Compare and contrast solar and lunar eclipses as regards cause, duration, frequency, nature, &c.

Solar.	*Lunar.*
1. solar eclipses can occur only at conjunction or "no moon."	1. Lunar eclipses can occur only at opposition or Full Moon.
2. Solar eclipses may be total, partial, or annular.	2. Lunar eclipses may be only total or partial, never annular.

Solar.	*Lunar.*
3. The sun is really shut out from view and eclipsed.	3. The moon is *not* shut out from view, and therefore not eclipsed but only obscured.
4. Solar eclipses are of a very brief duration, lasting at the most 8 or 12 minutes.	4. Lunar eclipses are of much longer duration, lasting as long as two hours.
5. Solar eclipses are seen only from a very small part of the earth.	5. Lunar eclipses are seen from more than half the earth.
6. Solar eclipses always begin on the western edge of the sun and move towards the eastern.	6. Lunar eclipses always begin on the eastern limb of the moon and finish off on the western.
7. In the case of solar eclipses, when one part of the earth is seeing the sun totally eclipsed, other parts may see it more or less partially eclipsed.	7. Lunar eclipses, whether total or partial, appear the same to all parts of the earth where they are visible.

80. What phenomenal changes would take place if the orbits of the earth and moon were to lie in the same plane?

If the orbits of the earth and moon were to lie in the same plane, there would be a regular succession of solar and lunar eclipses at every conjunction and opposition, making a total of 26 eclipses in a year, none of which, however, would be partial. For, at every conjunction the moon would get into a straight line between the earth and the sun, so as to cover the disc of the sun behind its own ; and at every opposition it would dip into the earth's shadow and be obscured.

81. Describe the appearance of the Moon as seen (i) with the unaided eye, and (ii) with a telescope. What conclusions can be drawn from these observations as to the possibility of life on the moon?

(i) When looked at with the unaided eye, the moon presents a mottled surface some portions of which are darker than others. These darker portions, before the age of the telescope, were believed to be lunar seas and oceans ; but observation since the invention of that useful instrument has proved them to be mountains nd hills and valleys.

(ii) In the telescope the surface appears pitted all over with great *craters*, very similar to the volcanic craters on earth, but of an immensely greater size. In them there is no sign whatever of present volcanic activity. There appear, also, many deep, narrow, crooked valleys, now dry, but believed once to have been water-courses and hence called *rills*. Then there are numerous straight *clefts*, hundreds of miles long and about half a mile wide. Telescopic observation has further shewn the total absence of air and of water, and therefore also of clouds, of storms, of snow, and of vegetation, on the surface of our satellite.

Hence, it would not be difficult to believe that the moon is entirely destitute of animal or vegetable life such as exists on our earth, since it is wanting in the two most essential supporters of such life, *viz.* air and water.

82. To what conclusion are we led regarding the earth from telescopic observations of the moon's surface?

The numerous craters on the moon's surface have shown no sign of activity since observation with the telescope first began. They are believed to be the remains of volcanoes that were once as active as any now on earth. But the moon, being a body much smaller than the earth, has lost its internal heat much sooner. The earth, in consequence of its much greater size, is cooling more slowly. The volcanic eruptions now are probably not so furious as they were some thousand years ago. Hence it is argued that the time will at last come when the earth shall have parted with so much of its heat that it will no longer be able to provide volcanic phenomena, and then we shall pass into the quiescent stage which the moon attained long ago.

83. How can it be proved that the moon has neither water nor atmospheric air ?

That the moon has no atmosphere is proved (1) by the telescope, and (2) by the absence of refraction when the moon comes between any more distant object, as the sun or a star, and ourselves.

(1) The telescope shows no distortion of surface, no haze, no twilight, no cloud, no sign of storm or of any other phenomena caused by the atmosphere of the earth.

(2) The sun's limb remains perfectly clear and even during a solar eclipse. Moreover, when a star, even the brightest one, comes in a

line with the moon, the occultation and the reappearance are always *instantaneous*. Neither of these facts would happen if the moon had an atmosphere of even a slight density, which would cause the star to dwindle down in brightness before the opaque body of the moon had advanced far enough to shut it out.

That there is no water on the moon is sufficiently proved by the absence of atmospheric air and of clouds.

84. Why does the moon come every day later to the meridian of a given place ? Or,

Explain why the moon keeps on losing on the sun.

In 24 hours the earth finishes one rotation and returns to the same position with regard to the sun; but in the meantime the moon has advanced so far in its path round the earth, that the latter has to continue its rotation 50 minutes longer before the moon can once again reach the meridian of the given place.

In other words, the moon's apparent motion in the heavens is 27 times slower than its apparent motion in the sky*; consequently, the former simply appears as a sort of *lagging back* during the diurnal movement.

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* For the distinction between *sky* and *heavens*, see note on Ques. 88.

The result is that the moon returns to the meridian of a place not in a solar day of about 24 hours, but in about 24 hours and 50 minutes.

85. How many times does the moon turn on its axis in a year?

In the course of a year the moon makes 13 complete rotations and about a third of a 14th rotation on its axis, because it turns once round in about $27\frac{1}{3}$ days, which number when dividing 365 gives about $13\frac{1}{3}$ as quotient.

86. Why does the moon always present the same half of its surface to the earth? Describe experiments to illustrate your answer.

As the moon goes round the earth, at the same time it slowly turns on its own axis, the peculiarity being that the times of one revolution and one rotation are very nearly the same. Its day and night are, therefore, each about a fortnight long, and *in the long run* it always presents the same side to the earth.*

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*Really, the moon shows much more than half its surface at one time or another. About 41 per cent. of it is always visible, 41 per cent. always invisible, and the remaining 18 per cent. alternately visible and invisible. The reason is that the times of rotation and revolution are not *exactly* the same; the former is a fixed period, the latter varies a little. Besides, the moon's axis is slightly inclined to the plane of its orbit, so that sometimes one pole, sometimes the other, comes a little more in view. This appearance of a little more than half of its surface now on this side, now on that, is called the moon's "Libration".

Experiments: (*i*) Suppose a man to take hold of a lamp-post fixed in the ground, with both hands, and to go round and round it, always keeping his eyes on the post. He would in a short time get giddy,—thus proving to himself that he has both *rotated on his own axis* as it were, and revolved round the lamp-post in exactly the same time.

(*ii*) Place a ball on a table in the middle of the room to represent the earth. Tie one end of a string to a nail in one of the four walls about four feet from the floor. Stand facing the ball and the nail, and tie the other end of the string to the highest button of your coat. Now walk round the table, always keeping your face towards the ball. When you return to the place from which you started, you will find that the string has coiled once round your body. This shows that while revolving round the table you have inadvertantly rotated on your axis too.

87. What reason have we to say that the moon performs its rotation and revolution in the same period ? Illustrate your answer by experiments.

That the moon performs its rotation and revolution in the same period is proved from the fact that it always presents the same half, or nearly the same half, of its surface to the earth.

Experiments:—Same as in the last question.

88. How many apparent motions has the moon, and how many real ?

The moon has two apparent motions, one in the sky, the other in the heavens.† The former is due to the earth's diurnal rotation, and therefore seems to lie towards the west. The latter is caused by the moon's revolution round the earth, and therefore appears in its real direction, *viz.*, towards the east.

The real motions of the moon are :—

(1). The monthly revolution round the earth.*

(2). An annual revolution round the sun as the satellite of the earth.*

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† Astronomers make a distinction between the terms *Sky* and *Heavens*, which are popularly regarded as synonymous. By "the sky" is understood that imaginary surface along which the heavenly bodies seem to move, whereas "the heavens" is a term used to express the numerous shining bodies themselves.

*The combined effect of these two revolutions (round the earth and round the sun) is, that the motion of the moon is a very complicated one, for it is actually moving round a body which itself is in constant motion. Hence the moon describes round the heavens a continuous spiral line which returns into the same course only after 18 years. (See Ques. 53.)

(3). A forward movement in space towards the constellation Hercules, as a member of the Solar System.

(4). A rotation upon its own axis, completed in *very nearly the same time as that occupied by its revolution round the earth.*

89. Why does the moon appear sometimes very high and sometimes very low in the sky ?

The plane of the moon's orbit makes an angle of nearly 29° with the plane of the equinoctial circle of the heavens. Consequently, the moon gets sometimes 29° above and sometimes 29° below the equinoctial, so that there is a difference of no fewer than 58° between the highest and lowest points that the moon can reach in the sky.

90. What are the "horns" of the moon ? What determines their direction ?

The *cusps*, or points of the crescent, are popularly called the "horns" of the moon. They are always turned away from the sun and equidistant from him, since the illuminated convex curve must face the sun, and the concave curve between the horns is the "terminator" or the line separating the dark half from the bright.

91. What do you understand by "the old moon lying in the arms of the new"? How do you account for that phenomenon?

Two or three days before or after the new moon, the whole of the moon is visible, the illuminated crescent being, of course, brighter than the rest of the disc which shines with a pale reddish light. This is popularly known as "the old moon lying in the arms of the new." The pale reddish light is not directly from the sun, but is sunlight reflected back from the earth, which, as seen from the moon, is then nearly full, and shines with a light about 15 times as strong as the light of the full moon.

92. Explain the phenomenon of the Harvest Moon.

Though the moon arrives at the meridian of a place about 50 minutes later every day, yet it sometimes happens that it *rises from the horizon* at almost the same hour on successive nights. The reason is that at these times its oblique motion, caused by its lagging back in the heavens, lies in a course nearly parallel to the plane of the horizon. This phenomenon occurs once every lunation, but is most conspicuous at the time of harvest in September, and is called the Harvest Moon, since the moon then rises every night at the same hour as if for the express purpose of assisting in the work of harvesting.

93. Does the moon exert any influence on the earth ? If yes, mention, without explaining, of what nature it is.

Popular superstition attributes many changes in the weather and conditions of life on earth to the influence of the Moon. Science recognises only two, — first, the tides in the ocean, and secondly, certain disturbances in terrestrial magnetism when the moon comes to the perigee or apogee.

THE PLANETS.

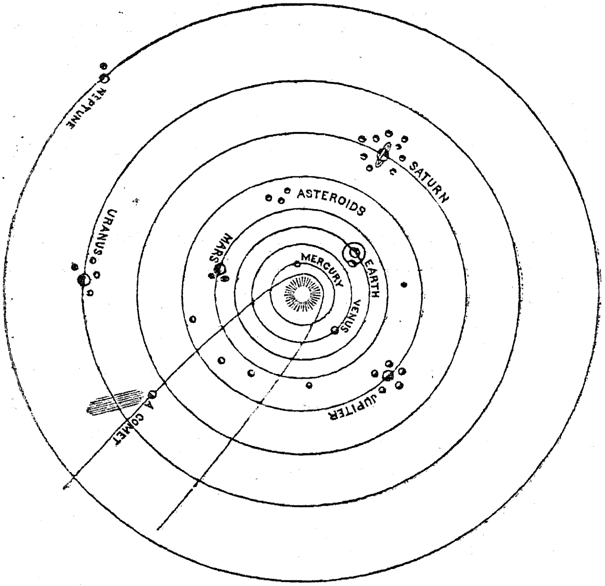

Fig. 13--The Solar System.

95. Of what does the Solar System consist, and why is it so called?

The *Solar System*, from L. *sol*, the sun, is the name given to a certain group, or system, of heavenly bodies which are influenced by the sun as the central power. The System consists of:—

(1) *Eight large Planets*, called the Primary Planets, because they revolve round the

sun as their centre of attraction. Their names, in the order of distance from the Sun, are Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.

(2) About twenty *Secondary Planets*, otherwise called Satellites or Moons, attendant upon the larger or Primary Planets.

(3) About 400 *Minor Planets*, otherwise called Planetoids or Asteroids, revolving round the Sun between the orbits of Mars & Jupiter.

(4) *Meteoric Bodies*, which at times approach near the Earth's orbit, and occasionally reach the Earth's surface.

(5) *Comets*, which are probably white-hot masses of gas, which rush towards the Sun, go round him, and then rush away again.

(6) The *Zodiacal** *Light*, a faint beam of light stretching from the sun both ways along the ecliptic through the constellations of the Zodiac (whence the name) and clearly visible

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* The student must be careful not to confound the Zodiacal Light with twilight, which is only sunlight reflected from the upper portions of the earth's atmosphere after the sun has set, and which lasts until stars of the sixth magnitude become visible. The duration of twilight varies from half an hour to two hours according to latitude.

across the sky in the evening after the twilight has faded, or in the morning before the dawn appears. Though its true nature and position in the system have not yet been determined, it is supposed to be sunlight reflected by a vast swarm of meteorites revolving round the sun.

96. What is a Planet? Mention particulars in which stars differ from planets. How do you distinguish between stars and planets at night?

A planet is a dark or non-self-luminous body travelling round the sun and shining by his light. The name *planet*, or 'wandering star,' was given to such bodies to distinguish them from the so-called 'fixed stars.' The word comes from the Greek *planetes*, a wanderer.

Planets differ from stars in the following particulars:—

(1.) Planets are dark bodies, shining by light borrowed from the sun.	(1.) Stars are self-luminous bodies, like the sun itself.
(2.) Planets travel round the sun, and continually change their position with regard to the sun and the stars.	(2.) Stars do not move or change their position with regard to the sun or to another.

(3.) Planets, when seen through the telescope, present a flat, circular disc to the eye,—at least those that are near enough to be seen.	(3.) Stars merely look like little points in a telescope; even the most powerful instruments will only make them look brighter, but will never show them with perceptible discs. This is probably due to their immense distances from us.

Stars are distinguished from Planets at night, thus:—

(1.) Stars always twinkle.	(1.) Planets shine with a steady brilliant glow.
(2.) Stars do not change place with regard to one another, though they seem to move in a body owing to the Earth's rotation.	(2.) Planets, besides seeming to move owing to the Earth's rotation, do at the same time change place among the stars. This change of place becomes easily perceptible in a careful observation of a planet for a few nights in succession.

97. What figure is described by a planet in its path round the sun? What position does the Sun occupy within that figure?

The paths described by the planets round the sun are all ellipses, with the sun not in the centre but at one of the two foci. Some of these ellipses are much more eccentric* than others. The orbit of the earth, for instance, is an ellipse of small eccentricity.

NOTE—This is the first of the three laws of planetary motion, commonly known as *Kepler's Laws*. (See Appendix.)

98. Define an Ellipse, and show how to draw one.

An *Ellipse* is a plane figure such that the sum of the two distances from any point on its

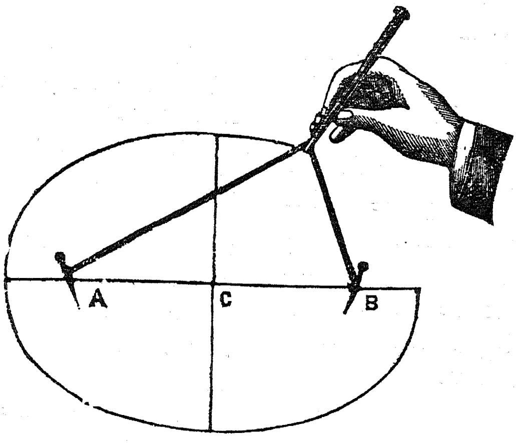

Fig. 14.—An Ellipse, and how to describe one. A, B, Foci; C, centre.

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* An ellipse is said to be eccentric when it is much wider across in one direction than in the direction transverse to this.

circumference to two fixed points within, called the *foci*, is always the same.

To construct an ellipse, fix two pins in a drawing board. Tie a loop of string a little longer than the distance between the pins. Place the loop on the pins and stretch it by means of a pencil. Keep the pencil in the loop and move it round, so that a curve will be traced similar to that shown in Fig. 14.

The greatest diameter of the ellipse is the major axis, and the least diameter is the minor axis. The point of intersection of these two axes is called the centre of the ellipse.

The Eccentricity of an Ellipse is the distance between the centre and one of the foci expressed in terms of the semi-major axis.

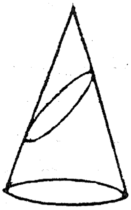

Fig. 15.

Note—If a cone is cut across obliquely by a plane, the section is an ellipse.

99. When is a planet said to be in aphelion and when in perihelion ?

A planet is said to be *in aphelion* when it is in that part of its orbit which is farthest away from the sun; (Gr. *apo*, from; *helios*, the sun). It is said to be *in perihelion*, when it is nearest to the sun (Gr. *peri*, near; *helios*, the sun). (See Ques. 54).

100. Into what groups are planets divided?

Planets are divided into two groups according as they revolve within or without the orbit of the Earth. Mercury and Venus, which are within the orbit of the Earth, are called *Inferior or InteriorPlanets;* Mars, Jupiter, Saturn, Uranus, and Neptune, which are all without the orbit of the Earth, are called *Superior or Exterior Planets*.

Humboldt has classified the planets in two groups,—the *terrestrial planets*, as he calls them, and the *major planets*. The terrestrial group contains the four planets nearest the sun, *viz.*, Mercury, Venus, the Earth, and Mars. The four others, Jupiter, Saturn, Uranus, and Neptune form the other group,—the Major Planets. (For points of difference between the two groups, See Ques. 108).

101. Define (i) Conjunction and Opposition of a planet, (ii) Inferior and Superior Conjunctions of a planet, (iii) Elongation of a planet from the sun, and (iv) Quadrature of a planet.

(i) When a planet and the sun are in the same general line of vision as seen from the earth, so that they perform their diurnal revolution round the earth together, the planet is said to be *in Conjunction*.

When a planet is on the opposite side of the earth to the sun, so that it rises at sunset and sets at sunrise, it is said to be *in Opposition*.

Thus, as will be seen from Fig. 16, an Inferior Planet will twice get into conjunction during each revolution round the sun, but never into opposition; a Superior Planet only once in conjunction, and once in opposition.

(ii) Of the two conjunctions of an Inferior Planet, the one in which the planet is between the Earth and the Sun is called *Inferior Conjunction*; the other, in which the Sun is between the Earth and the Planet, is called *Superior Conjunction*.

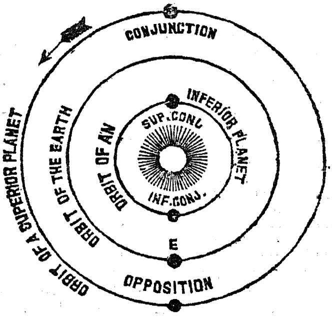

Fig. 16.—Conjunction and Opposition.

(iii) The Elongation of a planet from the sun is the angle between the two straight lines drawn from the centre of the earth to the centres of the planet and the sun. In the case of Mercury the greatest elongation, east or west, is 29°; for Venus, it is 47°; for a superior planet, the elongation may have any value between 0° and 180°. (See Ques. 122).

(iv) Quadrature occurs when the elongation of a planet from the sun is 90°. Hence, the Interior Planets, Mercury and Venus, can never be in Quadrature.

102. State the distances, in millions of miles, of the several planets from the sun.

The mean distances of the several planets from the sun are as follows, though at times they are much nearer to or farther away from him owing to the eccentricity of their orbits:—

Mercury ...	36	millions of miles ...	$\frac{1}{3}$ *
Venus ...	67	,, ...	$\frac{2}{3}$
The Earth...	93	,, ...	1
Mars ...	142	,, ...	$1\frac{1}{2}$
Jupiter ...	483	,, ...	5
Saturn ...	886	,, ...	$9\frac{1}{2}$
Uranus ...	1,800	,, ...	19
Neptune ...	2,800	,, ...	30

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*This column shows the *relative* distances of the planets from the sun, the distance of the Earth being taken as unity.

103. Give the Rotation Periods and Periodic Times of the eight principal planets.

Planet	*Rotation Period.**	*Periodic Time.*†
Mercury	24 hours.‡	88 days
Venus	23¼ ,, ‡	225 days.
The Earth	24 ,,	1 Year.
Mars	24½ ,,	1 yr.11 mths
Jupiter	10 ,,	12 yrs.
Saturn	10½ ,,	30 ,,
Uranus	9½ ,,	85 ,,
Neptune	......	164 ,,

104. Distinguish clearly between a planet's sidereal and synodic periods. Which

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* Observe that the first four planets have *nearly* the same rotation period, as also have the next three.

† For the relation of periodic times and mean distance from the sun, see Kepler's third law, Appendix.

‡ A doubt has been raised as to the correctness of these two figures since the observations published by Schiaparelli, an Italian astronomer, who lately tried to prove that these two planets have the same length of rotation periods as their respective periodic times, *viz.*, 88 days and 225 days. (See Ques. 110).

of the two is meant when we ordinarily speak of the periodic time of a planet ?

The sidereal period of a planet is its time of revolution round the sun, from a star to the same star again, *as seen from the sun*. The synodic period is the time between two successive conjunctions (or oppositions) of the planet with the sun, *as seen from the earth*. The times given in the second column of Ques. 103 are sidereal periods and are generally referred to as periodic times.

105. How are astronomers able to determine the length of a planet's day ?

When a planet is seen in the telescope, it does not present a uniformly bright disc, but there appear marks or spots upon it here and there. One of these spots which happens to be distinct and well-defined is selected by the astronomer for observation. As it is watched from hour to hour, it appears to be slowly moving along the disc in a straight or curved line. When it comes to the edge of the disc, it disappears for a time and then makes its appearance again on the other side of the disc, as if during the period of its disappearance it had been moving on the side of the planet turned away from us. Then it moves on to the point where it was when first selected for observation. The time it took to complete one such journey is noted, and it is allowed to start again on a second journey, and a third, and so on. Similarly, other spots are watched at other times; and when the times taken by all of them for a single journey are found to be the same, it is concluded that the spots are not moving but fixed in the body of the planet whose axial rotation made them *seem* to move. Hence, the time determined for a single journey of the spots is laid down as the rotation period of the planet. (See Question 142).

106. Which of the planets are attended by satellites? How many has each?

Planet	*Satellites.*	*Planet*	*Satellites.*
Mercury	0	Jupiter	7
Venus	0	Saturn	10
The Earth	1	Uranus	4
Mars	2	Neptune	1

107. Distinguish between the primary and secondary planets.

The Primary Planets are the eight large planets which revolve round the sun as their centre of attraction.

The Secondary Planets are those which, like our moon, revolve round a primary planet as centre of attraction, independent of the revolution of the latter round the sun. They are otherwise known as *Satellites*.

108. In what particulars do the terrestrial planets differ from the major planets?

(1). The terrestrial planets are very small bodies compared with those of the major group, and have a comparatively small number of satellites revolving round them.

(2). The matter of which they are composed is dense compared with the matter of the major planets.

(3). They rotate upon their respective axes more slowly than the major planets.

(4). When seen through the telescope the terrestrial planets look brighter at the limb (*i. e.* at the circular edge) than at the centre; the reverse is the case with the major planets.

(5). The terrestrial planets are comparatively free from the thick layers of clouds with which the major planets are enveloped.

(6). It is also very probable that the major planets are at a high temperature and emit a certain amount of light of their own.

109. Mercury is exceptional in the solar system in various ways. Mention these ways.

(1). It is the *nearest* planet to the sun, and therefore *receives the most light and heat*, and is the *swiftest in its movement.*

(2). It has *the most eccentric orbit*, with the *greatest inclination to the ecliptic.*

(3). It is the *smallest in diameter*, and therefore has *the least mass*, but (probably) it has the *greatest density* of all the planets.

110. Describe the appearance of Mercury as seen through a telescope.

As seen through the telescope, Mercury looks like a little moon, showing phases precisely similar to those of our satellite, with this difference that, whilst our Moon always keeps nearly the same apparent size, Mercury shows a change not only of shape but also of size. At inferior conjunction the dark side is towards us ; at superior conjunction, the illuminated surface : these are new Mercury and full Mercury respectively. Between these two the planet shows the crescent, the half, and the gibbous phases as does our moon.

The surface of the planet presents very little of interest. It is brighter at the edge than at the centre, but there are no markings clear enough to give us sufficient information as to its geography or even its rotation.

Certain permanent markings upon the surface of Mercury were discovered in 1889 by an Italian astronomer who in consequence announced that he had ascertained that the planet completed one rotation on its axis in the same time as one revolution round the sun, *viz.*, 88 days ; in other words, *it kept the same face always turned towards the sun*, just as the moon does towards the earth. This discovery, however, has not been confirmed by other astronomers, owing to the great difficulty in making the necessary observations. (See note on Ques. 103).

111. Mercury can never be overhead at midnight: why not ? What are the times for the watching of Mercury ?

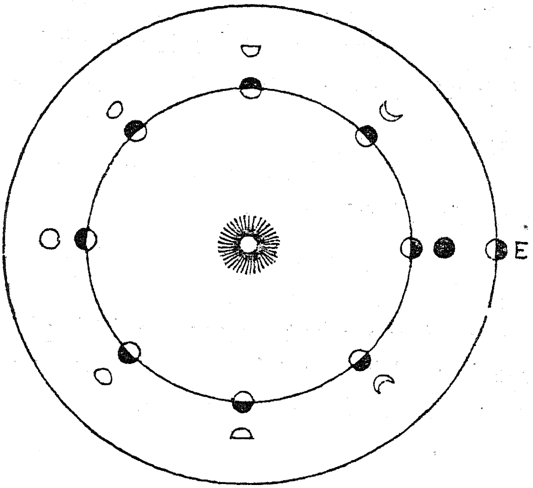
At midnight the sun is exactly below our feet, so that the earth comes between the sun and a body right overhead. But Mercury being an Inferior Planet, it is impossible for the earth to get between that planet and the sun. Hence, Mercury can never be overhead at midnight.

Mercury, being the nearest planet to the sun, is always found in close attendance on him, so that it can be seen only low down in the west just after sunset, or low down in the east just before sunrise. And even then it cannot always be seen, as it is buried in the dazzling sun-light for the greater part of the year. It only gives a glimpse every now and then, and disappears as swiftly as it comes in view. Hence, we must be always on the look-out if we want to see the little planet, sweeping with our telescope the eastern or the western horizon in the mornings or evenings.

Note. If seen after sunset, it cannot, of course, be seen before sunrise the next morning,

112. Describe the appearance of Venus as seen through a telescope.

The telescopic appearance of Venus is striking on account of her great brilliancy ; but it is at the same time exceedingly unsatisfactory because she presents no distinct surface-markings,—nothing but occasional darkish shadings, which may possibly be continents and oceans, or simply breaks in clouds, through which the planet itself is seen.



Fig, 17.—Phases of Venus, showing change of shape only.

Like our moon and Mercury, Venus, too, shows different phases when seen through the telescope; but, like Mercury and unlike our moon, she changes her size too, with change of phase. When she is nearest to us, *i. e.*, near her inferior conjunction, she is only 25* millions of miles from us; when she is farthest away from us, *i. e.*, near her superior conjunction, she is 160† millions of miles from us. Hence, the crescent of Venus will appear to form part of a circle 6 times as large as that presented by Venus when she is full to us. Hence, also, the crescent of Venus is much more brilliant than full Venus, because the gain of brilliancy from the diminution of distance more than compensates for the small part of the illuminated side then turned towards us.

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* Distance of Earth from the Sun is $92\frac{1}{2}$ millions of miles; distance of Venus from the sun is $67\frac{1}{2}$ millions of miles; $\therefore$ distance of Venus from the Earth is $92\frac{1}{2} - 67\frac{1}{2} = 25$ millions of miles.

113. Of what astronomical importance are telescopic views of Mercury and Venus ?

Telescopic views of Mercury and Venus afford important evidence about the rotation and revolution of the Earth, and thereby prove the truth of the Copernican system as against the Ptolemaic.‡

114. When is Venus the Morning and when the Evening Star ?

When Venus is to the west of the sun as seen from the earth, she rises before the sun and is called the Morning Star, or Lucifer (*i. e.* light-bearer.) When she is to the east of the sun as seen from the earth, she sets after him, and is called the Evening Star or Hesperus.

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† $92\frac{1}{2}+67\frac{1}{2}=160$ millions of miles,

‡ See Appendix,

115. How long does Venus continue as Morning Star, and how long as Evening Star ?

If the Earth were stationary and Venus only were moving round the Sun, then she would be the morning star one half of *her* year (*i. e.* 112 days), and the evening star the other half. But as the earth also moves round the sun in the same direction as Venus, the relative motion of the latter, in respect to the earth, is much slower than her absolute motion in her orbit. Hence, she is the morning star for nearly 290 days, and evening star for 290 days, thus taking a year and seven months to run through her changes.

119. Explain fully, with the help of a diagram, how Venus appears alternately as the Morning and the Evening Star.

When Venus is in Sup. Conj., she cannot be seen for a few days, as she rises and sets with the sun. After this time she falls to the east of the sun and sets after him, and is then called the Evening Star. Every day she recedes further from the sun eastward, till she reaches her Greatest Eastern Elongation, which is about 47°. At this point her direct or eastern motion slackens, the sun begins to gain upon her, and she appears stationary as regards her motion among the stars. Then she begins to retrograde until she is so near the sun again as to be lost in his dazzling light. She is now in her Inferior Conjunction. When next she comes in view, it is not on the western horizon but on the eastern as Lucifer or the Morning Star. From this day she continually increases her distance from the sun, till she reaches her Greatest Western Elongation. Here she begins to retreat and comes nearer to the sun every day, till once more she is in the place from which she started, *viz.*, Sup. Conj., when for a few days she remains invisible. She takes a year and seven months to run through the whole of this course, which is termed her synodic period.

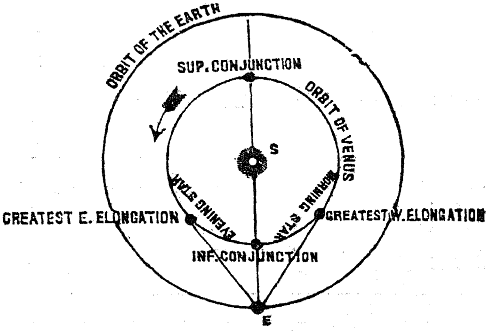

Fig. 18.—Venus as Morning and as Evening Star.

Note.—The motion of Mercury with regard to the sun is precisely similar to that of Venus, its greatest elongation being about 29°.

117. What is meant by a Transit of Venus? Of what duration is it? And at what intervals do such transits occur?

When Venus is at inferior conjunction it sometimes* happens that she comes in a right line between the earth and the sun. She is then visible even to the naked eye as a black spot on the disc of the sun, crossing it from east to west. This phenomenon is called a "Transit of Venus," *i e.*, a passing of Venus across the sun's surface.

A transit, if central,† lasts about 8 hours; when non-central, the time varies with the track pursued.

A transit of Venus, however, is a very rare occurrence; the last took place in 1882, the next will not be till the year 2004 A.D. The periods of recurrence can be seen from the following dates of their past and future occurrence:—

Dec. 7, 1631.
Dec. 4, 1639.

June 5, 1761.
June 3, 1769.

Dec. 9, 1874.
Dec. 6, 1882.

June 8, 2004.
June 6, 2012.

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* *Sometimes* only, because the orbits of Venus and the Earth are not in the same plane.

† A phenomenon, like a transit or eclipse, is called *central* when the body traverses the diameter of the object through or over which it passes.

118. Why do not transits of Venus occur at every inferior conjunction of the planet ?

See question 117, foot-note, and reason out as in Question 62.

119. Why have the transits ot Venus been observed with so much care ?

A Transit of Venus, whenever it has occurred, has been watched with great care and expense, not only on account of the beauty or singularity of the event, but because it affords a valuable means of solving important astronomical problems. When observations of the transit of Venus made at opposite sides of the earth are brought together, we are enabled to calculate from them the distance of Venus, and knowing that, we can find the distance of the sun and the distances and sizes of the several planets. This is very valuable information and, therefore, no wonder that astronomers try to make the most of such transits when they occur.

120. Are there transits of any other planet like those of Venus ? If yes, say anything you know regarding them.

Yes, there are transits of Mercury similar to those of Venus, and rather more frequent, but of no great astronomical importance, except for accurate determination of the planet's own position.

Of the other planets no transits can occur, because their orbits are without the orbit of the earth so that they cannot get between the sun and the earth.

121. How is it proved that Venus is within, and Jupiter without, the orbit of the Earth ?*

That Venus is within, and Jupiter without, the orbit of the Earth, is proved from two observed facts about the planets :—

(1) Venus is sometimes seen to cross the sun's face, like a small black spot upon it ; Jupiter never does so. In other words, there occur transits of Venus, but never of Jupiter.

(2) Venus never gets further from the Sun than about one-fourth of the visible celestial hemisphere, and is never seen for more than three or four hours before sunrise or after sunset. Jupiter goes any distance from the Sun, being at times even directly opposite to it, and then dominating the heavens all night long.

123. (a) How many times is Mars smaller than the Earth ? (b) Describe its general appearance as seen through the telescope.

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*The question, expressed in general, would read as follows :—How are astronomers able to say whether a planet is Inferior (or Interior) or Superior (or Exterior)? The student should attempt an answer to this question himself after reading answer to question 121.

(*a*) The diameter of Mars is nearly half that of the Earth, so that its *surface* is about two-sevenths, and its *volume* one-seventh of the earth's.

(*b*) Since the orbit of Mars is outside that of the earth, Mars never presents the *crescent* phase like Mercury and Venus; but at quadrature it becomes distinctly *gibbous*, and looks like our moon three days before or after full moon.

When looked at with the eye alone, Mars appears of a reddish tint and cannot be easily distinguished from the fixed stars in its neighbourhood. When seen through a telescope, the redness somewhat disappears and the planet exhibits a bright disc with definite markings, which may be broadly divided into three classes:—

(i) There are two *white patches* near the planet's poles, supposed to be masses of snow or ice, since they behave exactly as the polar snowcaps of our earth. The northern patch gets smaller during the northern summer, when the North Pole of the planet is turned towards the sun, while the southern patch grows rapidly larger; and *vice versa* during the southern summer.

(ii) About three-eighths of the planet's surface is covered with *patches of a greenish shade* supposed to be bodies of water.

(iii) Nearly five-eighths of the surface is covered with *vast tracts of various shades of orange and yellow*, suppossd to be land.

From these and other well-marked spots upon the planet's disc its period of rotation is determined with great accuracy.

A certain amount of atmosphere also, much less copious than that on earth, has been occasionally detected surrounding the globe of Mars.

Besides, careful telescopic scrutiny has shown that the chief features of this planet are of a permanent character.

There is also seen a net-work of dark lines or dusky bands, which are believed to be artificial canals dug for irrigation.

Hence Mars is a very interesting object in the telescope, presenting itself with its continents and oceans, its snows and air, as a miniature picture of our own world.

124. When is Mars the best situated for observation ?

When Mars is in opposition, it is at its nearest point to the earth; and fully illuminated. This is the best time to examine the planet. Its orbit, however, is so very eccentric or oval, that it is at one opposition much nearer to the earth than at another. Now, if an opposition happens with Mars in perihelion and the Earth in aphelion, the distance between the two planets is the *shortest possible*, and this is the most favourable time for observation. Such seasons recur about every two years, when for months together Mars is a very brilliant object in the skies every night and a very interesting one in the telescope.

125. Describe the appearance of Jupiter as observed with the naked eye and with a telescope.

To the naked eye Jupiter appears as a large bluish star, with a peculiarly soft and steady light.

In a telescope, even a small one, Jupiter is a very beautiful object, looking as large as our moon even when farthest away from us. The planet shows no perceptible phases. It appears of an oval shape, being much more flattened at the poles than our earth. But what specially distinguishes this planet from all the others is a number of bands, or *belts*, running across its disc parallel to the equator, and frequently changing their form as the atmospheric conditions of the planet are altered. These belts are now generally believed to be openings in the clouds by which Jupiter is supposed to be surrounded. The axis of Jupiter appears, from the movements of the belts, to be very nearly vertical to the plane of its orbit. Consequently neither pole can be ever turned towards the sun, and there can be no such variety of seasons as we have.

126. What is the number of Jupiter's satellites? Explain, by means of a diagram, the phenomena connected with these satellites.

Till very recently Jupiter was known to have only four satellites, but in 1892 (September 9) a fifth one was discovered, of size not more than a hundred miles in diameter. Since then two more have been added to the number.

These little moons, when watched from the Earth, present quite a beautiful sight, running round the giant planet at various rates. Their orbits (except that of the fourth) are but slightly inclined to the plane of Jupiter's orbit, and this single circumstance accounts for the three remarkable phenomena of what are known as the *Transits*, *Eclipses*, *and Occultations of Jupiter's Satellites.* These terms may be defined as follows:—

A *transit* of a satellite of Jupiter is an apparent passage of the satellite across the disc of the planet as seen from the earth.

An *eclipse* of a satellite of Jupiter is a hiding of the satellite in the shadow of the planet. It is the same as an eclipse of our moon.

An *occultation* of a satellite of Jupiter is a disappearance of the satellite *from our view* behind the planet, but *not* in its shadow.

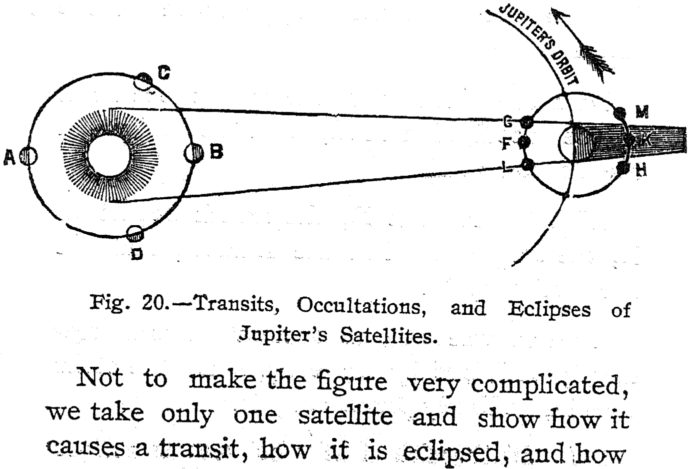

Fig. 20.—Transits, Occultations, and Eclipses of Jupiter's Satellites.

Not to make the figure very complicated, we take only one satellite and show how it causes a transit, how it is eclipsed, and how occulted.

When the earth is at A, none of these occurrences can be seen on account of the dazzling light of the Sun coming between the planet and us.

When the earth is at B, an occultation is impossible, and the eclipse cannot be seen by us. We can then only see the transit at F.

The best time for observing all these phenomena is when the planet is at or near quadrature, *i. e.*, when the earth is at C or D. For then Jupiter's shadow projects so far to one side that the whole of the eclipse takes place clear of the disc, and we can watch both the disappearance and the re-appearance of the satellite.

With the earth at C, the transit occurs at G, the occultation at H, and the eclipse in the shadow at K.

With the earth at D, the transit occurs at L, the eclipse at K in the shadow, and the occultation at M.

Thus in one case an occultation is immediately *followed* by an eclipse, in the other case immediately *preceded* by it.

127. Distinguish clearly between an eclipse and an occultation of a satellite of Jupiter.

(1.) An eclipse is a burying of the satellite in the shadow of the planet.	(1.) An occultation is simply a disappearance of the satellite *from our view* behind the planet, but *not* in its shadow.
(2.) During an eclipse we can see the satellite if the earth is favourably situated.	(2.) During an occultation we can never see the satellite.
(3.) An eclipse is a *gradual* phenomenon, in which the satellite becomes slowly fainter and fainter as it enters the shadow, and reappears in the same leisurely way.	(3.) In an occultation the satellite disappears the moment it touches the planet's disc, and reappears as suddenly on the other side in a short time.
(4.) In an eclipse, the sun's rays are entirely cut off from the satellite by the body of the planet coming between.	(4.) In an occultation, the satellite is illumined by the sun, though unseen by us.

128. Of what astronomical importance are the eclipses of Jupiter's satellites ?

The eclipses of Jupiter's moons have been observed with great care by astronomers, because they enable them to determine (1) the exact longitude of places on earth, and (2) the velocity with which light moves through space.

(1.) Suppose an eclipse of a satellite of Jupiter is calculated to occur at 12 midnight, Greenwich time (longitude 0°). Now if an astronomer at any other town would see that eclipse at 1 a. m. of its local time, this town must be 1 hour's space, or 15°, to the east of Greenwich. If another astronomer at another town would see it at, say, 10 p. m., this town must be 2 hours' space, or 30°, to the *west* of Greenwich. And so on for any other town. (See Ques. 27 and 33 above, and Q. 143 below.)

(2) In 1675, the Danish astronomer Roemer found that the eclipses of Jupiter's satellites did not occur at the exact time he had calculated for them. When Jupiter was in conjunction with the sun, (*i. e.*, farthest away from us), they happened 16 min. 36 sec. later than when it was in opposition (*i. e.*, nearest to us). Roemer believed that this

difference in time was really the time taken by light to traverse the diameter of the Earth's orbit, by which length the planet is farther from us at conjunction than at opposition. (See Fig. 16). He took the diameter of the earth's orbit at 182,000,000 miles, and by a simple rule-of-three sum found that the velocity of light must be 186,000 miles per second. This conclusion has been verified by two independent experimental methods since the time of Roemer.*

129. In what respect does Saturn differ from the rest of the planets ?

The planet Saturn is quite a unique member of the Solar System, in having, besides the largest number of attendant moons, *a system of thin, flat, concentric rings* round the middle of the planet.

130. Describe the general appearance of Saturn as seen with the naked eye and through the telescope.

To the naked eye Saturn appears as a pale, yellowish white star of the first magnitude.

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* At present, therefore, the case is reversed. Instead of determining the velocity of light from the distance of the sun, the distance of the sun is determined from the velocity of light.

In the telescope it is, indeed, a beautiful object with its ten little moons and three brilliant rings surrounding the globe. It presents an elliptical face of clear pale light, surrounded by a flat, broad, illuminated ring. It resembles its neighbour Jupiter in having its disc shaded at the edge, and in showing a number of belts parallel to the equator, which are, however, faint compared with those on Jupiter.

But the most remarkable feature of the planet is its beautiful *ring system*. These rings are three in number, one outside another, the diameter of the outermost one being 166,000 miles. They are very broad, but so thin that when their edge is turned towards us they appear, even in the most powerful telescopes, as nothing more than a fine needle of light piercing the planet's ball. The inner and the outer bright rings are separated by a dark line, which can be traced all round the globe. At the inner edge of the inner ring begins a strange structure called the *crape ring*, which extends half way towards the globe of the planet, and which is remarkable for its semi-transparency in as much as it sometimes allows the globe of the planet to be seen right through it.

As to the structure of the rings, there was long a difference of opinion among astronomers. Now it is universally admitted that they are mere *swarms of separate particles*, possibly an infinite number of small moons, revolving round the planet in a common plane; though it is still an open question whether the rings form a permanent system, or will be broken up at some future day.

131. Why are not the satellites of Saturn of equal importance with those of Jupiter ?

The moons of Saturn, though ten in number, are of no importance for astronomical purposes for two reasons :

(1.) The planet is so very far from us that we cannot observe the eclipses and occultations of its moons as easily as we do those of Jupiter's.

(2) The orbits of Saturn's satellites are so much inclined to the orbit of the planet itself, that these phenomena are very rare.

132. Mention any peculiarity about the planet Uranus.

Little is known of this planet, owing to its immense distance from our earth. The only peculiar feature known so far is, that its satellites seem to be moving in a direction contrary to that of all the other members of the Solar System, except the only known satellite of Neptune.

133. Explain the circumstances that led to the discovery of Neptune.

Soon after the discovery of Uranus (1781 A.D.), it was found that the planet did not keep to the path marked out for it from calculation, and astronomers at once set about determining the cause of its deviation. Remembering the law of *universal attraction*, they believed at first that the error must have been due to the pull on Uranus of Jupiter and Saturn, the largest of the planets and nearest to it. When, however, they had made allowance for this cause in their calculation, there still remained some difference which they could not understand. It was then suggested that there must be another planet outside the orbit of Uranus, responsible for this irregularity of the latter. Calculations were accordingly made, and the position of the new planet was accurately determined. Strange to say that when the telescope was directed to that place in the heavens, the unknown planet was at once found out and the whole mystery about Uranus's irregularity was solved (1846 A.D.). This discovery is one of the greatest triumphs of modern science, and shows how far Mathematics can be applied to the science of Astronomy.

134. Which of the other planets must have seasons similar to those on the earth, and why ?

The principal causes of our seasons are (1) the inclination of the Earth's axis to the plane of its orbit, (2) the consequent inequality in the lengths of day and night, and (3) the *parallelism* of the Earth's axis to itself.

Now, if any other planet have its axis inclined to the plane of its orbit *at about the same angle* as the Earth's, then we may conclude that, *ceteris paribus*, it must have seasons similar to ours. This, according to our present knowledge of the planets, is the case with Mars and Saturn only, whose axes are inclined to the planes of their orbits at 25° and 27° respectively, the Earth's being $23\frac{1}{2}°$. This conclusion is supported by the general appearance of Mars, especially the polar snow-caps, which alternately increase and decrease during a Martian year.

135. Is it possible for life, such as we know on Earth, to exist on any of the other planets ? Explain your answer fully.

This is a question which has been keenly disputed by men of opposite opinions, but to which we can never possibly get a correct answer, unless, perhaps, we pay a personal visit to the brothers and sisters of our mother Earth, millions of miles away! At present we can only deal in idle conjectures based on what these uncles and aunts of ours look like through our magnifying eye-glasses.

Comparing the physical features and conditions of the other planets with those of our Earth, we find that Mars is the only one that resembles our planet in any plausible degree, though it too differs in several particulars. Hence, *if* life, such as we know on earth, can exist anywhere else, Mars is the place.

If, however, we argue from analogy, we should deem it *probable* that the planets support life of some kind or other; for, when we see every possible nook on the surface of our great globe crowded with teeming life, we hesitate to believe that so many more stupendous orbs have been left without it. Besides, most of them seem to possess an atmosphere like our own, which makes it easier to believe the existence of life on them possible.

136. What are the Asteroids? What position do they occupy in the Solar System? What is the current belief among astronomers as to their formation or origin?

The Asteroids, also called Planetoids or Minor Planets, are a large family of small planets revolving round the sun between the orbits of Mars and Jupiter and forming part of the Solar System. Some of these planets move in orbits so very eccentric that they resemble comets rather than planets in this respect, and are hence sometimes known as ultra-zodiacal planets, *i.e.*, planets lying beyond the Zodiac. (See Ques. 163.) The first of them was discovered on the night of January 1, 1800, and the number of those since discovered exceeds four hundred. Many new ones are added every year by means of improved methods of observation and by the aid of photography. The names of the first four in order of discovery are Ceres, Pallas, Juno, and Vesta.

According to Bode's Law (see Appendix), they occupy the place of a fifth planet in order of distance from the sun, and hence their origin has been accounted for in one of the following two ways. They are supposed to be the fragments of a fifth planet of the terrestrial group, which *either* failed in its formation owing to the powerful attraction of the giant Jupiter, *or* which afterwards broke to pieces somehow or other. The former of these two hypotheses is now generally accepted, as the latter cannot explain some of the peculiarities in the orbits of these planets.

THE SUN.

137. Write brief notes on the Sun under the following heads : form, size, and position.

Form:—The Sun is believed to be an enormous globe or sphere, from the fact that the spots on its surface *appear* to move just as they would do if they were carried along on the surface of a rotating sphere. (See Ques. 142).

Size or Magnitude:—The magnitude of the Sun may best be understood by a comparison of its dimensions with those of the earth.

	Earth	Sun
Diameter	1	110
Surface	1	12,000
Volume	1	1,300,000
Weight or Mass ...	1	332,000

Position:—The sun is the centre of the Solar System, round which the planets all move in elliptical orbits with the Sun in one of the foci.

138. What is the distance of the sun from the earth ? Mention, without explaining, the methods that have been used to ascertain this distance.

The sun's distance is *variable* owing to several causes, the chief of which is the eccentricity of the earth's orbit. The difference between the distances at aphelion and perihelion is as much as 3 million miles. The mean distance is 92,975,500 miles.

This distance is determined in various ways, all of which give the same result :—(1) by means of the Aberration of Light :—(2) by finding the sun's horizontal parallax, *i.e.*, the semi-diameter of the earth as seen from the sun; (3) by knowing the velocity of light, which is about 186,000 miles per second, and applying that knowledge to observations of eclipses of Jupiter's satellites*; (4) by observations of Transits of Venus; and (5) by observation of Mars at opposition.

139. What is the length of the sun's diameter? How has the length of the sun's diameter been calculated?

The Sun's diameter is about 866,500 miles in length.

If the sun's distance and apparent size be known, the length of its diameter can be determined in the following way :—

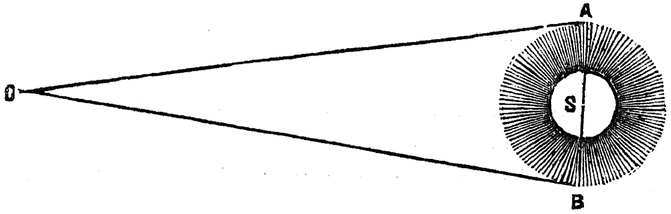

Fig. 21.—How to determine the length of the Sun's diameter.

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* See note on Ques. 128.

In fig. 21, let O be an observer on earth, and S the sun. From O draw two imaginary lines OA and OB to opposite sides of the sun, so that AB is the diameter whose length is to be calculated. Now, if the angle AOB be accurately measured, it will be found to be such that AB, the base of the isosceles traingle AOB, is $\frac{1}{107}$ of AO or BO. And as AO or BO is known to be about 93,000,000 miles, dividing this number by 107, we get about 866,500 miles as the length of the sun's diameter. This is about 108 times the diameter of the earth.

140. Name and explain the principal phenomena on the sun's surface when seen through the telescope.

(1.) The *Photosphere*, or *light-sphere*, popularly called the *disc*, is the round, flat surface that we see every day. In the telescope it shows a rather darkish background, sprinkled over with grains, or *nodules*, as they are called, of a much brighter appearance.

(2.) On the Photosphere there appear occasionally certain *dark spots*, that are continually changing in shape, size, and position. By their passage across the disc from east to west, they indicate an axial rotation of the sun from west to east.

(3.) Besides the dark spots there are also found scattered over the sun's surface certain very bright streaks called *faculæ*. They are more conspicuous near the *limb* or in the neighbourhood of the spots. They consist of the same material as the rest of the photosphere, but are higher than the surrounding surface, and therefore much more brilliant than the rest.

(4.) Outside the photosphere lies the *chromosphere*, or *colour-sphere*, so called from its brilliant scarlet appearance. During a total solar eclipse it presents a beautiful sight and looks very much like "a prairie on fire."

(5.) Outside the chromosphere, and shooting out of it, are seen occasinally huge flames of fire, called *Prominences*. They are clouds of incandescent gas, as was proved during the Indian eclipse of 1868.

(6.) Beyond these red flames or prominences is the *Corona*, a halo or glory of light, commonly divided into the inner and outer coronas. The inner corona is intensely bright and of a pearly tinge; the outer becomes gradually fainter as it recedes from the disc, so that its end is not very well defined. Both the coronas can be seen with the naked eye during a total eclipse of the sun. The light issuing from them is at least twice as great as that of the full moon. The phenomena of the corona are not yet well understood, though it has been proved to be caused somehow or other by the solar atmosphere.

141. State, in separate paragraphs, the current belief among astronomers about the nature and constitution of the several phenomena that take place on the surface of the sun.

(1) As to the condition of the *central mass* or *nucleus* of the Sun, we have no definite knowledge. It is *probably gaseous*, this being indicated by the sun's low mean density and high temperature; but at the same time this gaseous matter must be in a very different condition from gases as we know them on earth, on account of the intense heat and the enormous pressure due to the force of solar gravity.

(2) The Photosphere is in all probability a sheet of luminous clouds, constituted

mechanically like terrestrial clouds, *i. e.*, of minute solid or liquid particles floating in gas.

(3) The Chromosphere and Prominences appear for the most part as if formed of *jets* of heated hydrogen, ascending through the interspaces between the photospheric clouds, like flames playing over a coal-fire. The Prominences may be divided broadly into two classes, *quiescent* and *eruptive*. The former are of immense size, are not very brilliant or rapid in movement, and do not much change while they are visible; they appear in all parts of the sun's disc. The latter appear only in the region of the spots; they are usually small, brilliant, and rapid in movement, and change almost every moment.

(4) As to the Corona, many of its phenomena are still unexplained, and since it has been observed only during the brief moments of total solar eclipses, progress in its study has been necessarily slow.

142. Write brief notes on the Sun-spots, describing their appearance, and explaining their cause, nature, astronomical importance, and any other facts that you may be knowing about them.

When the sun is looked at through a telescope with proper precautions so as not to injure the eye, there appear upon its surface certain dark spots which form, no doubt, the most interesting objects for an observer. They differ very much from one another in size and shape; they are continually changing in form; and they are always short-lived, lasting most of them for a month or two. They are in some years much more numerous than in others, the maximum recurring about every ten or twelve years.

Appearance of Sun-spots:—When a fully formed spot is observed in the centre of the Sun's disc, it usually presents three distinct shades of darkness. The intensely black part in the centre consists of a number of round spots, called *nucleoli*, but better known as *Dawes' holes*, after the name of their discoverer. Round this is a nearly circular portion less dark, called the *umbra;* round the umbra is a still less dark portion called the *penumbra*. As the spot moves from the centre of the disc towards its limb, the outer edge of the penumbra becomes gradually broader, the inner edge narrower; and, when the spot is on the point of disappearing on the other side of the sun, the inner edge of the penumbra altgoether ceases to be seen.

Experiment:—To illustrate the movement of a normal sun-spot, we would make a saucer-shaped cavity in a globe, paint the bottom of the cavity black to represent the umbra, and the sloping sides gray to represent the penumbra. Then as the globe is made slowly to rotate on its axis placed vertical with regard to the cavity, the appearance would be exactly such as a normal sun-spot presents.

Motions of Sun-spots:—When a well-marked spot is seen in the centre of the sun's disc, it is found every day to move slowly towards the west, then to disappear behind the disc, after a few days to re-appear on the eastern side, and to move again towards the centre. This one journey from centre to centre takes about 25 days.

What the Sun-spots prove:—A great number of these spots have been carefully watched from time to time, and have been found to move all *in the same direction* (from east to west), and all *in nearly the same time* (about 25 days). Hence the conclusion is that the sun must be rotating on its axis *from west to east* in about 25 days. (See Ques. 105).

Recent observation, however, has shown that all spots do not complete a rotation in the same time; those near the equator go round once in 25 days, whilst those farther away require more time in proportion to their distance from the equator, until the outermost ones in lat. 40° take fully 27 days. The only conclusion that can be arrived at from this difference in movement is that the sun's surface must not be solid, and that the different portions must be free to move with reference to one another like the waves of the ocean. This still awaits further investigation, and it is possible that at some future day our present theory about sun-spots will have to be completely altered.

Nature of Sun-spots:—The spots are, no doubt, *hollows* in the Sun's photosphere, but hollows filled with gases and vapours cooler than the rest of the surface.

Cause of Sun-spots:—Nothing certain can be said on this point. A number of theories have been proposed, of which the most satisfactory is that which considers these spots as the effect of *eruptions*. When an eruption takes place, a *hollow* or *sink* is caused in the surface, in which hollow the cooler gases and vapours collect.

Region of Sun-spots:—The spots are not found over the whole surface but are confined to regions 40° on each side of the solar equator.

Influence of Sun-spots on the earth:—One influence of sun-spots upon the earth is now established without doubt, though the nature and cause of the connection is not yet understood. Whenever the spots are numerous, the earth suffers many and violent magnetic disturbances ; delicately suspended compass needles oscillate about their true position ; and auroras are more frequent. Another influence, only recently recognized by European and American astronomers, was declared long ago by the late Prof. Kero Laxuman Chhatre of Deccan College, Poona. In 1879, he proved that the quantity of rainfall at a place can be almost definitely predicted from the number, shape, and size of sunspots seen. His investigation led him to the conclusion that the rainfall is the greatest or least just four years after the appearance of the most or least numerous spots. He also proved that the fourth (or fifth) and tenth years after the least numerous spots are the years of famine in India. This discovery still awaits confirmation.

143. What is the composition of the sun? Name some of the substances to be found on the sun. In what state do they exist?

By the most improved methods of observation it has been discovered that the solar atmosphere contains many of the chemical elements (more than thirty-six) known on earth, but only *in the form of vapour or gas.* Some of them are iron, hydrogen, magnesium, carbon, copper, zinc, silver, tin, lead, and potassium. One noticeable feature is that all the elements hitherto found in the sun, except carbon, are *metals*; and that the most important terrestrial non-metals, as oxygen, nitrogen, chlorine, sulphur, and phosphorus, are conspicuous by their absence.

A new element, unknown on earth, has been discovered in the atmosphere of the sun, and called "helium", from Gr. *helios*, the sun.

144. How many real motions is the sun believed to have, and why?

The sun is believed to have two real motions of its own, (1) a rotation on its axis, and (2) a forward movement in space towards the constellation Hercules. The former is proved from the movements of the spots on its surface. As to the latter, Sir W. Herschel believed that he could indicate a point in the constellation Hercules towards which the sun was rapidly advancing, because he found that the stars in that part of the heavens seemed to be wider asunder than they once did. Similar observations of stars in the southern hemisphere have shown that the stars in some parts of the heavens seem to be getting closer to-gether.

Illustration :—A man approaching a cluster of trees sees them wider apart as he comes nearer; whereas, on receding from them, he finds them getting closer to-gether.

145. The sun, it is said, has been radiating heat into space for millions of years : how, then, is its temperature maintained at a constant degree ?

Two theories have been propounded to account for the constant temperature of the sun. The first is that the myriads of meteorites moving round the sun are drawn into it and help to keep up its light and heat. The second is that the sun, being a ball of luminous matter, is continually contracting in size, by which contraction enough heat is generated to make up for the entire loss.

The second is the more generally accepted theory, since the first would account for only a small fraction of the lost heat being restored, whereas it has been calculated that by the contraction of only $\frac{1}{10000}$ th part of its diameter enough heat would be generated to last for 2,000 years.

146. Which class of celestial bodies does the Sun belong to, and why?

The Sun is believed to be one of the millions of twinkling little stars with which the heavens are so thickly studded. But it is by no means the biggest of the stars as might appear at first sight. Its greater size and heat and light are due only to its being the nearest star, being 500,000 times nearer to us than the nearest stars. Similarly, it is believed that the stars are all so many distant suns, each of which is the centre and head of a family of planets like our own.

COMETS AND METEORS.

147. What is a comet? Why is it so called?

A Comet is a celestial body, moving in a very eccentric orbit and having a vapour-like appendage, called the *Coma*. The word *Comet* is from Gr. *Cometes*, long-haired—from the long tail of comets,—because, when seen with the naked eye a comet looks like a little star surrounded by a luminous fog and having a long tail of hazy light.

148. Describe the general appearance of a Comet.

A Comet, when bright enough to be seen with the naked eye,* *may* generally show the following features:—

(1). The *Coma*, a faint cloud of bright transparent matter. This is the *essential* part of a comet, without which there can be none.

(2). The *Nucleus*, a bright star-like point near the centre of the comet.

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* It is, however, a rare event. Most comets are mere wisps of light, seen only with powerful telescopes. Hardly half a dozen are visible to the naked eye in a century. The last such appeared in 1882 and remained visible for about six months. The next appearance of a splendid comet that is predicted is of the Great Comet of Halley about 1910.

(3). The *Tail*, or *Train*, a stream of light stretching for millions of miles behind, and always pointing in a direction away from the sun. It seems as if certain materials present in the comet were driven away from the head by the intense heat of the sun and formed the tail. The tail, therefore, is not a permanent part of the comet.

(4). *Envelopes* or *Jets* of light issuing from the nucleus as the comet approaches the sun.

Note.—Comets, however, vary so much in shape, size, and brilliancy, that no two are exactly alike; in fact, their forms are almost as various as those of the clouds.

149. Sketch, in brief, the movements of a comet.

Comets make their first appearance as small, faint, and slowly-moving bodies. In a little time they quicken their motions and augment their splendours, throwing out long tails behind them and rushing head-long towards the sun. When they have come nearest to the sun, they take a sudden swoop around him and come out on the other side, where they begin their retreat into space. Then they slacken their speed, gradually lay aside their glories, and at last dissolve once more into inconspicuous telescopic specks, which very soon disappear altogether.

150. What place do Comets in general hold in the Solar System ?

Comets do not form regular members, so to speak, of the solar household, but are only looked upon as *visitors*. This is because (1) the orbits of most of them are sensibly parabolic, (2) their planes have no evident relation to the ecliptic, and (3) most of them go round the Sun the contrary way to planets, and have what is called a *retrograde* motion. They are considered as wanderers in space, attracted at times by our sun and then running away from him with an infinite velocity to visit some other of the innumerable distant suns. Some of them, however, have been *naturalized*, so to say, and obey the central power of our sun like the planets.

151. If comets are only visitors to the Solar System, how is the periodical return of certain of them to be accounted for ?

It is clear that those comets which move in *parabolic* orbits cannot be regarded as anything more than visitors to our system. As to those which move in *elliptical* orbits, returning as regularly as the planets themselves, it is a question whether they are to be regarded as *native-born* or only as *naturalized*.

The explanation usually given is this:—That all comets come to us from interstellar space. That some of them are so powerfully drawn by the giant planets of our system, that they cannot go out again, and in course of time settle down as regular members of the family. This is known as the *Capture Theory of Comets* and is generally accepted by astronomers.

152. What points, (i) of resemblance, and (ii) of difference, do you note between planets and comets?

(i). Comets resemble the planets in only two particulars, *viz.* in shining by light borrowed from the Sun, and in wandering through space, unlike the fixed stars.

(ii). Comets differ from the planets in the following respects:—

(1). Planets are composed of earthy and watery substances such as are found on our earth.	(1.) Comets are composed of *thin vapour*, through the densest portions of which stars of the faintest luster remain perfectly visible.
(2). Planets show *well-defined* and equally illuminated *discs*.	(2.) Comets present themselves as patches of *confused cloudy* light.

(3). Planets keep a *fixed* and *immutable* aspect while they are visible.	(3.) Comets *continually change* their form and aspect while they are in sight.
(4). The orbits of planets are *nearly circular* ellipses, with the sun in one of the foci.	(4.) The orbits of comets are *mostly very elongated* ellipses, one end of which lies near the sun, and the other end far away from it.
(5.) Planets move round the sun and complete their revolutions in fixed periods.	(5). Comets, whenever seen in the sky, are either *advancing towards* or *receding from* the sun. They approach the sun within a certain distance, go round it, and then fly off from it into distant realms.
(6). Planets confine themselves to the ecliptic and neighbouring zones of the sky.	(6). Comets make their fitful appearances indifferently in all possible regions of the visible heavens.
(7). Planets, moving as they are in nearly circular orbits, do not suffer any great variations	(7). Comets move in more eccentric ellipses than planets, and consequently they must

of heat and cold, the winter and summer being due not to the distance from the sun, but to the stoop of the axis.	suffer greater variations of heat and cold than the latter.
(8). Planets move round the sun all in the same direction, from west to east.	(8). Comets mostly revolve from east to west and are said to have a *retrograde motion*.

153. What is the probable nature and constitution of comets?

Nothing definite can be said on this point. The hypothesis, most generally accepted, is that the head of a comet is a swarm of meteoric particles,* each enveloped in a gaseous covering and shining either by electric discharges or by the light of the sun. The elements most generally found in comets are carbon and hydrogen ; sometimes also iron, lead, sodium, and a few other metals are detected.

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* See Ques. 158.

154. What are Meteors and Meteorites? By what other names are they known?

Meteors are transient, luminous, star-like bodies, seen to dart quickly across some portion of the sky and then suddenly disappear, leaving sometimes, for a few seconds, a train of light behind. They are otherwise known as *Bolides*, *falling stars*, or *shooting stars*.

Note.—Formerly, astronomers made a distinction between meteors and shooting stars, from the fact that the latter make no sound, and almost never reach the earth's surface. Of late years, the distinction has come to be disregarded, and it is believed that shooting stars are just like other meteors except only in size, being so small that they are entirely consumed in the air before anything of them can reach the earth's surface.

Meteorites are pieces of stone or iron which have fallen to the earth from space. In other words, they are the remains of meteors too large to be entirely consumed in the air. They are also called *Aerolites*, *Uranolites*, or simply *meteoric stones*.

155. Which other class of bodies in the Universe do meteors resemble, and why?

The meteors, though popularly called shooting stars, are no stars at all, since they are not self-luminous. They are of *the nature of planets* and are illumined by the light of the sun only, though they cannot be seen by us on account of their comparatively very small bodies. When they *fall*, as we say, from their place and enter the earth's atmosphere, they move at such a rapid rate that by friction they catch fire and show themselves as *shooting stars*. They are ultimately melted and turned into vapour. When the heat subsides, the vapour condenses again into fine dust, which is scattered along the track of the meteor. The small ones are reduced to ashes before they can reach the earth; the larger ones are melted on the outside and considerably reduced in size, though not entirely consumed.

When meteoric stones are examined by chemists, they are found to contain elements that are all known to us on earth, and this is the reason why meteors are believed to be fragments of planets (or of comets) moving round the sun like our earth and other planets. Hence, also, the reason why they are included in the Solar System.

156. How would you distinguish a meteorite from an ordinary terrestrial stone?

A meteorite is distinguished from an ordinary stone by the thin, black, varnish-like coating, which is formed, no doubt, by the fusion of the surface during the meteor's swift flight through the air. As a rule, the surface of a meteorite is smooth but uneven, having *thumb-marks* upon it, which are probably caused by the fusion of some of the softer materials.

157. What are Meteoric showers? How are they caused? Give the dates and names of some of the more common ones.

It sometimes happens that meteors, instead of showing themselves at intervals here and there, appear in *showers* of hundreds and thousands, all proceeding or *radiating* from a single point in the sky. These showers are evidently caused by the earth's passing through a swarm of meteors on her journey round the sun.

The following are some of the well-known meteoric showers :—

(1) The August Meteors (August 10), called Perseids, because they seem to come from the constellation Perseus.

(2) The November Meteors (Nov. 13), called the Leonides, because they seem to come from the constellation Leo.

(3) The Andromedes (Nov. 27 or 28), so called because they seem to come from the constellation Andrâmêda.

In some years these showers are far more numerous than in others. For instance, the Leonides make a grand display of themselves every 33 or 34 years. They appeared in 1833, and again in 1866 as had been predicted, and were expected to return in 1899 or 1900, but have not returned as yet for reasons still to be investigated.

158. What are the grounds for saying that comets are but swarms of meteorites?

From a careful examination of the shape, size, and position of the orbits of the meteoric swarms that have appeared at various times ; and from a comparison of these orbits with the orbits of some of the periodical comets, it appears, beyond the possibility of a doubt, that there is a real and close connection between these two classes of bodies. Besides, it is known (1) that comets are not very hot, (2) that they do partly consist of solid matter, and (3) that the vapour they give off may be obtained from a substance found in meteorites.

Putting all these facts to-gether, there seems to be much truth in the belief that prevails among astronomers, that " the comet itself is only the thickest part of the meteoric swarm, and that the clouds of meteors scattered along its path are the result of its *disintegration*."

THE STARS.

159. Discuss the appropriateness of the term "fixed" as applied to the stars.

Though the stars are commonly called "fixed" to distinguish them from the planets which are *wanderers*, yet they are really subject to certain slight amounts of motion which can be detected only by refined instruments. They are, however, at such inconceiveable distances from us that their swiftest motion becomes imperceptible except in the long run.

Astronomers know of two kinds of motion among stars,—*common* and *proper*. The *common* motion is shared by all stars in the same part of the sky and is only an apparent motion; the *proper* motion is peculiar to individual stars and is a real motion. Of this latter kind of motion, even the swiftest is too small to be noticed by a casual observer, being only a degree in about 15,000 years. There is no wonder, therefore, that the stars stand to-day in the same position with regard to one another as we find them in the charts and catalogues made 2,000 years ago.

160. How are stars classified?

Before the invention of the telescope, the stars were divided into six classes according to their brightness. These classes were called *magnitudes*. Thus, about twenty of the brightest stars in the heavens were classed to-gether as stars of the *first magnitude ;* those next in brightness were called stars of the *second magnitude ;* and so on. The sixth-magnitude stars could hardly be seen by an ordinary eye.

After the invention of the telescope, the same system was extended to the smaller stars, and we have now stars of the seventeenth and eighteenth magnitudes, or even lower still.

No settled system, however, has been followed in the classification of these telescopic stars, so that the magnitudes assigned to them by different observers are very different.

Note.—The word *magnitude* in this instance denotes the degree of *brilliancy* and not of *bulk.*

161. What is the number of stars ?

Though we hear it popularly said that the number of stars is infinite, yet careful observers have essayed to count them, and from the average of records of several of them the number of *lucid** stars may be laid down at

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* The term *lucid* is applied to the stars that can be seen with the naked eye without the help of any instruments other than concave spectacles used by short-sighted people.

7,000 for the whole celestial sphere. When the telescope is brought to work, the number increases so rapidly that there are believed to be no fewer than 125,000,000 stars in all heavens.

162. What is the colour of stars ?

Most of the stars are white, but there are many of a somewhat ruddy colour. A few telescopic stars are intensely red ; some are even blue or green, while others show beautiful golden tints.

163. What is a Constellation ? How many Constellations have been known till now ? What are the Zodiacal Constellations ? Name them.

From very ancient times the stars have been grouped artificially in what are called the *constellations*, which are given fanciful names from animals and objects which they seem to resemble. They are groups of stars not naturally connected but merely lying together in the same general direction as seen from the earth.

Over a hundred constellations are now generally recognized. Of these, twelve are called the *Zodiacal Constellations*, because they lie in the Zodiac (*i. e.*, Zone of Animals), or the portion of the heavens extending 9° on either side of the ecliptic, in which the sun, the moon and the principal planets always keep.

Their names are :—

Spring.	Aries (the Ram)
	Taurus (the Bull)
	Gemini (the Twins)
Summer.	Cancer (the Crab)
	Leo (the Lion)
	Virgo (the Virgin)
Autumn.	Libra (the Balance)
	Scorpio (the Scorpion)
	Sagittarius (the Archer)
Winter.	Capricornus (the Goat)
	Aquarius (the Waterman)
	Pisces (the Fishes).

164. What is meant by the "Annual Parallax of the fixed stars"?

The stars are at such enormous distances from the earth, that even the diameter of the earth's orbit, though 180 millions of miles long, is almost as a point in comparison. Hence, a star, though seen from two positions on the earth's orbit diametrically opposite to each other, still appears almost exactly in the same direction. With the most recent and delicate astronomical instruments, however, a star is found to undergo a slight change of position when observed at intervals of six months in which time the earth has completed one-half of its orbit. This difference in the apparent position of the stars is known as their Annual Parallax, and is considered a proof of the earth's revolution round the sun. (See Ques. 22).

165. Explain the meaning and nature of Binary and of Multiple Stars.

Certain stars, when seen through the telescope, are found to be made up of two or more stars lying close to-gether and physically connected, so that one revolves round the other. If there are only two such stars, the system is called a *binary* or *double star ;* if more, it is called a *multiple star.*

166. Write a brief note on the Milky Way.

The *Galaxy* or *Milky Way* (L. *Via Lactea*) is a luminous belt of irregular width and outline, which divides the visible hemisphere of the heavens into two nearly equal parts. It extends below the horizon and then round the earth to form a girdle about the heavens. It is clearly visible on a dark, cloudless night, when the moon is absent. In the telescope it appears to be made up almost wholly of small stars, of the eighth magnitude and lower; it also contains numerous star-clusters, but very few true nebulæ.

167. What is a star-cluster? How does it differ from a Nebula? How many kinds of Nebulæ are there? And what is their probable nature?

The *clusters* and the *nebulæ* are both faint clouds of shining haze like broken pieces of the Milky Way. They are groups of little stars varying in number from a hundred to many thousands. Those of them in which the stars are easily seen by a telescope of moderate power, are called *clusters;* while the others, requiring high powers to see the separate stars, as well as those which cannot be separated into stars even in the most powerful telescope, are called *nebulæ*.

Astronomers distinguish two kinds of nebulæ: (i) the *Resolvable Nebulæ*, in which the stars are separated under a very high power; and (ii) the *Irresolvable Nebulæ*, which still appear of a cloud-like structure, even in the most powerful telescopes.

Only two or three of the irresolvable nebulæ are visible to the naked eye. One of them, a very beautiful one, is in the sword of Orion. In the telescope their number amounts to as many as eight thousand.

As to the nature of the Nebulæ, nothing certain can be said as yet. They may be either masses of glowing or incandescent gas, or clouds of stones clashing to-gether and thus giving rise to a luminous appearance.

168. What is a Nebulous star?

Nebulous Stars are those which, when closely examined, appear to be surrounded by a kind of fog, resembling a nebula.

169. What are the grounds for believing that the Solar System is the result of a slow growth and not of an instantaneous creation. Explain clearly the hypothesis on which this belief is based.

It is commonly said that the earth, the sun, the moon, and all other heavenly bodies were created perfect from the first; but to a man of science, who has learnt to connect causes and effects, the case seems otherwise. He knows that the planets all move round the sun in elliptical orbits, in almost the same plane, in the same direction, and at regularly increasing distances; that the larger the planet, the faster it rotates on its axis; that they rotate and revolve in the same direction and nearly in the same plane; and that their satellites revolve round them in nearly the same plane and the same direction as those of the planets' own rotation.

From these and similar facts he argues that the planetary system was not built in an instant but grew up slowly by immutable laws of nature. Accordingly, he establishes a theory which he calls the Nebular Hypothesis. It was worked out in detail by the celebrated French Astronomer La Place about the beginning of the last century. The Theory asserts:—

1. That at some time in the past the matter of which the sun and the planets are composed was in the form of a nebula.

2. That under the action of its own gravitation, the nebula assumed a form approximately globular, with a motion of rotation.

3. That in consequence of the rotation, the globe would necessarily become flattened

at the poles, and ultimately, as the equatorial regions bulge out, it would throw off rings of nebulous matter, like the rings of Saturn. Thus it would become a nebulous star.

4. That the ring so formed would for a time revolve as a whole, but would in the end break up into globes revolving round the central globe as planets. These planets would, of course, keep the same direction of rotation as the ring had revolved.

5. That the planets thus formed might throw off rings of their own, and so form a system of satellites each one for itself.

This theory, now generally accepted, explains most of the facts of the solar system.

170. Explain clearly the relations that are supposed to subsist between the stars and the nebulæ.

The stars are supposed to be distant suns, which are each one the centre of a planetary system like our own. Hence, the Nebular Hypothesis, which traces the growth of our Sun and planets to a nebula in the beginning, can also be applied to show that the stars are formed by the coming together of the materials of which the nebulæ are composed.

171. Define Declination and Polar Distance, and explain the relation between the two.

The *Declination* of a star is its angular distance north or south of the celestial equator; + if north, − if south. It corresponds precisely with the *latitude* of a place on the earth's surface; it cannot, however, be called *celestial latitude*, because that term is applied to an entirely different quantity.

The *Polar Distance* of a star is its angular distance from the North or the South Pole of the heavens according as the star is to the north or the south of the Celestial Equator.

From these definitions it will appear that Declination + Polar Distance = 90°; so that if the one be known the other can be easily found out.

Note.—Parallels of Declination are small circles drawn parallel to the equinoctial, like the parallels of latitude on earth.

172. Explain fully the expression "First Point of Aries."

The First Point of Aries, or the Vernal Equinox, is one of the two points in which the celestial equator cut the ecliptic in the time of Hipparchus, 2,000 years ago. At this point the sun crossed the celestial equator and passed north-ward about the 21st of March. It was, therefore, taken as the starting point for reckoning the longitudes of stars, in the same way as the meridian of Greenwich is now taken as the starting point for measuring the longitudes of places on earth.

Owing, however, to the movement of the equinoctial points round the ecliptic known as the Precession of the Equinoxes (see Appendix) the equinoctial line no longer points to Aries but to the next constellation of Pisces. The name, however, is still preserved, and astronomers still call the position of the sun at the spring equinox the First Point of Aries and count the longitudes of stars from it.

173. Define Right Ascension.

The *Right Ascension* of a star is its angular distance from the first point of Aries, measured upon the celestial equator. It may also be correctly, and for many purposes most conveniently, defined as " the sidereal time at the moment when the star is crossing the meridian."

174. If you were asked to find out a certain star in the heavens, what particulars would you require to know concerning the

same? Explain how you would proceed to find the star after knowing these particulars.

The positions of heavenly bodies with reference to each other are determined in the same way as the positions of places on earth. To know where a city is, for instance, we require its latitude and longitude; and the point where the two circles (the parallel of latitude and the meridian of longitude) intersect each other is the position of the city. Similarly, to find out the position of a heavenly body, we require to know (1) its declination, which corresponds exactly to the latitude of the city, and (2) its right ascension, which corresponds exactly to the longitude of the city.

When these two are known, we proceed to determine its place in the following manner:—

Suppose the declination is given as +50°, and the R.A. as 15h. 30m. As the declination is +50°, we know that the star is 40° from the N. Pole. So we first look for the Pole-star, and then trace a circle round it with a radius of 40° length. The required star must be somewhere on the circumference of this circle. Next, we proceed to find the first point of Aries. To do this, we join the Pole-star with Beta Cassiopeiæ, and produce the line 90° from the Pole-star. This point is the First of Aries. Then, as the R. A. of the star is given to be 15h. 30m., we reduce this to degrees, reckoning 15° for an hour. This comes to 232½° east, which is the same as 127½° west, of the First of Aries. As it is not convenient to measure 232½° E., it being more than two right angles, we measure 127½° W., and join the point we come to with the Pole-star. The point of intersection of this line and the declination circle already determined, is the position of the required star*.

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* The following is another way to determine the same, after the declination circle and the first point of Aries have been found:—

If we have a sidereal, or astronomical, clock, we would set it so as to show—Oh. Om. Os, when the first of Aries is on our meridian, and wait still it shows 15h. 30m., at which time we may expect to see the required star on our meridian, at the point where the meridian intersects the declination circle already determined.

GRAVITATION, Etc.

175. Define Gravitation, Gravity, Weight; and distinguish them from one another.

Gravitation is that species of attraction or force by which all bodies or particles of matter in the universe tend toward each other ; it is also called "attraction of gravitation," "universal gravitation," and "universal gravity."

Gravity, as distinguished from gravitation, is the tendency of a body toward the centre of the earth.

Weight is the effect of gravitative force, especially when expressed in certain units or standards, as pounds, grams, etc.; hence, it is a measure of the force of gravity, and, being the resultant of all the forces exerted by gravity upon the different particles of the body, it is proportional to the quantity of matter in the body.

176. Enunciate the Law of Gravitation.

Any two particles of matter attract each other with a force which is proportional to their masses and inversely proportional to the square of the distance between them.

177. Explain how the Theory of Gravitation has been verified by the moon's motion.

The earth's radius is about 4,000 miles ; the moon's distance from the earth is about 240,000 miles. Consequently the moon's distance is about 60 times the earth's radius. Hence, on the hypothesis of gravitation, the force with which the moon is attracted by the earth ought to be $\left(\frac{1}{60}\right)^2$ or $\frac{1}{3600}$ of what it would be if the moon were at the surface of the earth. Now it is known that at the earth's surface a body falls 193 inches in the first second. The moon, therefore, ought to fall $\frac{1}{3600}$ of 193 inches, *i. e.*, ·0535 of an inch per second towards the earth. This it is actually found to do on calculation.

178. How are distances between heavenly bodies expressed ?

The apparent distance between two heavenly bodies cannot, of course, be measured in feet or yards. There is no meaning, for instance, in saying that two stars are three feet apart, unless we know how far from the eye the three-foot measure is to be held. A rupee held very close to the eye will conceal from view a large portion of the sky, but, re-

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179. Explain clearly how astronomers are able to determine the distances of heavenly bodies from the earth.

To ascertain the distance of a heavenly body from the earth, two places are selected on the earth's surface as widely as under as possible, *i. e.*, two places diametrically opposite to each other. From each of these places the angle which the heavenly body makes with the base-line is carefully measured, and the result furnishes a triangle of which the base and the adjacent angles are known. From these data the altitude of the body (*i. e.*, its distance from the centre of the earth) is calculated by the aid of Trigonometry.

If the body, *e. g.*, a star, is so far away from the earth that the 8,000 miles of terrestrial diameter become insignificant as a base-line, then the angular measurement is taken from opposite sides of the earth's vast orbit, which gives a base-line of nearly 190 millions of miles. Still even this base-line is found too short for most of the stars whose distances remain unknown in spite of the most refined instruments of observation.

180. How do astronomers know the composition of heavenly bodies ?

The composition of a heavenly body is determined from the colours into which a ray of its light can be split up. A beam of light from the body is passed through a prism which immediately separates it into its components. The different colours are then compared with the light given by different elements known on earth, and thus the substances which exist in the distant object are discovered. The process, however, is not quite so simple. The instrument employed for the purpose is called the Spectroscope.

APPENDIX.

A.—ABERRATION OF LIGHT.

Light, like sound and other physical forces, is not transmitted instantaneously, but with a definite velocity. This fact causes an apparent displacement of a distant object seen from a *moving* station, unless the motion is in a straight line towards or away from the object. This displacement is greater or smaller as the station itself moves faster or slower. Now, the earth moves in its orbit at the very rapid rate of 18½ miles per second, which causes the displacement distinctly perceptible in the case of the stars and even of the sun. Hence the following definition:—

Aberration is the apparent displacement of a heavenly body caused by the rapid movement of the earth in its orbit combined with the velocity of light.

Illustration I.—In order to see a star, a telescope is to be directed a little in advance of the true place of the star, which would not be the case if the earth were at absolute rest.

Illustration II.—A cannon ball striking the side of a ship in rapid motion at right angles to the direction of the course of the ball, will cut the ship *obliquely* from side to side. But if the ship be at rest, the ball will pass *straight on* to the other side.

Illustration III.—A man standing in a rain-shower when there is no wind, holds his umbrella in a vertical position over his head; if now he begins to run at a rapid rate, he will be obliged to hold his umbrella *sloping in front of him*.

B.—BODE'S LAW.

Towards the close of the 18th century (A.D. 1778), a curious numerical relation was announced by the Astronomer Bode to be existing between the mean distances of the several planets from the sun; and, though subsequent discoveries have shown it to be a mere coincidence, the relation is still recognised as "Bode's Law". It may be briefly explained as follows:—

Take the series of numbers:—

0 3 6 12 24 48 96 192 384;

Add 4 to each of these numbers, and a new series is formed, thus—

4 7 10 16 28 52 100 196 388;

divide each of these last by 10, and the series becomes

·4 ·7 1 1·6 2·8 5·2 10 19·6 38·8.

This series, with the exception of the last number, approximately represents the *relative* distances of Mercury, Venus, the Earth, Mars, the Asteroids, Jupiter, Saturn, and Uranus from the sun, as given in Ques. 102.

C.—KEPLER'S LAWS OF PLANETARY MOTION.

The famous German Astronomer, Kepler, was the first to shew that the planets revolve round the sun not in circular, but in elliptical orbits. After a careful study of the movements of Mars for several years, he proved that the orbit of that planet is an ellipse, and hence drew the same inference about the orbits of the other planets including the earth. He also demonstrated that the orbital motions of the planets are governed by three simple laws, since known as "Kepler's Laws." They are as follows:—

First Law.—*The planets move in ellipses having the sun in one of the foci.*

Second Law.—*The straight line joining a planet with the sun sweeps through equal areas in equal times.*

Third Law.—*The squares of the periodic times of any two planets are to each other in the same proportion as the cubes of their mean distances from the sun.*[*]

D.—FOUCAULT'S PENDULUM EXPERIMENT.

It has been stated in Ques. 12 above that the diurnal rotation of the celestial sphere can be explained in one of two ways only, either by supposing the earth to be at rest and the heavens to move round it, or the heavens to be at rest and the earth to spin on its axis. The former hypothesis was the current belief in the early stages of Astronomy in the absence of any instruments to aid observation.

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[*] This third law can be easily verified by the student with the help of the figures given in Ques. 102 and 103.

The invention of the telescope early in the 17th century gave altogether a new life to the science ; and observations made on the sun, moon, and many of the planets, which were *seen* to be rotating bodies, obliged several astronomers to abandon the older hypothesis and to believe, from *analogy*, that the earth, too, must be a rotating sphere. Many and varied were the attempts then made by men of opposite convictions to support or to overthrow the new hypothesis.

Among the large number of such experimental proofs, the celebrated pendulum experiment of the French philosopher Foucault (A. D. 1851) deserves the first place. He took a heavy ball of iron about a foot in diameter and suspended it from the dome of the Pantheon in Paris by means of a wire about 200 feet in length. Underneath the ball he made a small circular ridge of sand 12 feet in diameter, in such a way that at every swing of the pendulum a mark would be made in the sand by a pin attached to the ball. At first the ball was kept absolutely at rest in a slanting position by a cotton string which was then gently burned off to give the pendulum a free swing in a true plane. But this plane was seen to turn slowly to the right,

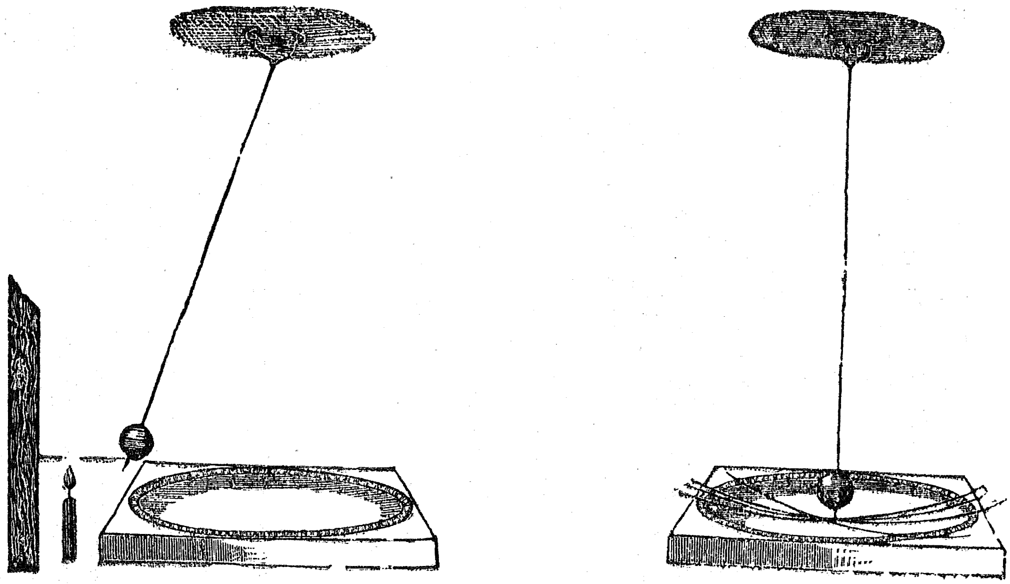

Fig. 22.—Foucault's Pendulum Experiment.

and the pin to scrape the sand in a new place at each swing, describing the arc of a circle which would have been completed in about 30 hours, had not the pendulum come to rest by the attraction of gravity. In fact, the floor of the building was seen to be *actually turning* with regard to the plane of vibration.

E—THE PRECESSION OF THE EQUINOXES, AND HOW IT IS CAUSED.

The *Precession of the Equinoxes* is the slow backward motion of the equinoctial points along the ecliptic, at the rate of 50″ annually. It is caused by the conical movement, or *wabbling*, impressed upon the axis of the earth in consequence of the action of the sun, moon, and planets upon the bulging matter about the equator, in connection with its diurnal rotation. It is so called because either equinox, owing to its westerly motion, comes to the meridian sooner each day than the point it would have otherwise occupied, and thus *precedes* that point continually with regard to the line of transit and motion.

F.—THE ULTIMATE RESULT OF THE PRECESSION OF THE EQUINOXES.

The equinoctial points move round the ecliptic at the rate of about 50″ per annum, so that a revolution is completed in about 26,000 years. The ultimate effects of this movement are—

(1) The north and south poles of the earth, as also the celestial poles which are opposite to them, move round the north and south poles of the ecliptic in 26,000 years. Hence, in a few centuries the present pole-star will have got a considerable distance away from the north celestial pole, and other stars will have taken its place one after another. (See note on p. 38).

(2) The seasons, which depend on the inclination of the earth's axis to the plane of the ecliptic, are, so to speak, slowly moving round the earth's orbit, completing a revolution in 26,000 years. After 13,000 years the constellation of Virgo which forms at present the back-ground of the sun at the Autumnal Equinox (September 21) will form its back-ground at the Vernal Equinox, and summer and winter, spring and autumn, will have changed places. And it will require 13,000 years more after that to bring the seasons back to their present condition.

G—THE ANNUAL PARALLAX OF THE FIXED STARS.

See Ques. 164.

QUESTIONS.

From the MATRICULATION PAPERS of the BOMBAY UNIVERSITY.

[The numbers in bracket at the end of each question refer to the Questions in the book before. The figures to the right indicate the full marks assigned at the examination.]

1860.

1. Explain the construction of the human eye, and show by a figure, that the image upon the retina is inverted with respect to the object. How do you account for long-sightedness and short-sightedness ?

2. Explain the costruction of the common astronomical telescope, and of the ordinary microscope.

1861.

3. (*a*). Give a *brief* account of the Solar System. (95).

(*b*). Explain the phases of the Moon. (55).

1862.

4. Describe the eye regarded as an optical instrument. Why is it that sometimes the reflexion of a star from the surface of water is a long strip of light and not an exact image ot the star ?

5. Account for the phases of the moon. Why does the moon rise at different times on two successive nights ? (55,84).

1863.

6. Define the terms *Apparent motion*, *Equator*, *Ecliptic*, *Orbit*, *Equinox*, *Parallax*.

7. State Kepler's Laws, and mention the conclusions respecting the Force of Gravitation deduced from them respectively by Sir Isaac Newton.

8. Explain the phenomena of the seasons. (19).

9. Distinguish carefully between the nature and causes of Solar and Lunar Eclipses respectively. (59, 60, 61, 63, 64, 66, 79).

1864.

10. Describe the motions of the Earth. (11, 24). 5

11. Explain the fact that in all places on the earth's surface lying in north latitude, the day is longer than the night when the sun is in the Summer Solstice. (18). 7

12. Explain the nature and cause of the Moon's changes of Phase. (55). 9

13. What is a Lunation? (94). 4

14. Why does the Moon always present approximately the same face to the Earth? (86). 7

1865.

15. A person travels from Bombay to Calcutta; state, giving clear reasons for your answer, whether his watch will appear to have gained or lost on his arrival at his journey's end. (28). 7

16. Explain the phenomena of the Seasons. (19). 8

17. What appearance would the Earth present to a spectator on the Moon's surface? (56). 8

18. Explain the nature of a Lunar Eclipse. 7

1866.

19. Define the terms *Parallax* and *Refraction;* and state the effect of each on the apparent position of the heavenly bodies. (164). 8

20. State and illustrate the Laws of Kepler. (Appendix). 12

21. When is a planet said to be in aphelion and when in perihelion? (99).

22. Explain the phenomena of Spring and Neap Tides. 8

1867.

23. State briefly any proofs that may occur to you (*a*) of the Rotundity of the Earth; (*b*) of its diurnal motion. (6, 12). 10

24. Explain how an Eclipse of the sun 8
is produced. Why does not one occur
every lunar month? (59,62).

25. What figure is described by a 6
planet in its path round the sun? What
position does the sun occupy within that
figure? (97).

26. What is the position in the Solar 10
System of the Planetoids or Asteroids?
What is Olbers' theory of their formation?
(136).

[Ans.—Olbers, the discoverer of *Vesta* (1807), was the originator of the theory of an exploded planet. See Ques. 136].

1868.

27. Of what does the Solar System 10
consist, and why is it so called? (95).

28. How are the Seasons to be ac- 7
counted for? (19).

29. How are the Tides occasioned? 12
Explain the phenomena of Spring and
Neap Tides.

30. What are the distinctive phenomena of a total eclipse of the Sun? Mention any that you have observed yourself. (71.) 8

1869.

31. What are the astronomical, and what are the physical divisions of the planets? Give lists of the Inferior and of the Superior Planets, of the Interior and of the Exterior Planets. How many Asteroids have been discovered? (100,136). 12

32. Has anything been lately discovered about the Composition of the Sun? (143). 7

33. Explain the Phases of the Moon, with diagrams. (55). 7

34. When can an eclipse of the moon happen? Draw a diagram. (60,66). 8

1870.

35. Shew that the day which is the longest to us is the shortest in the year to the inhabitants of Australia. (18,19). 7

36. On what days of the year does the Sun rise due east to all places on the surface of the Earth, and why? (18). 6

37. What is Venus called when it is to the east of the Sun? At what distance from the Earth is Venus at its inferior and its superior conjunction with the Sun? (114,112). 9

38. Give a brief description of what you know of the position, office, magnitude, and physical condition of the Sun. (137). 12

39. Why is it that the Solar Eclipse begins on the western limb, and the Lunar on the eastern? (70). 6

Describe the appearance of the Lunar Disc during the interval, when the solar or lunar eclipse is total. (72).

1871.

40. Name the bodies comprised in our Solar System. Distinguish between Primary and Secondary Planets. (95,107). 8

41. Define and explain the following:—Prime Vertical, Parallels of Declination, Parallax, Refraction. 6

42. Explain the cause of Tides. At what times do Spring and Neap Tides occur ? And why ? 8

1872.

43. (*a*) Name the Inferior and Superior Planets. Why so called ? (100). 10

(*b*) State the distances, in millions of miles, of the several planets from the Sun. (102).

44. (*a*) What is the general form of the orbits of the planets ? (97). 10

(*b*) When is the Earth said to be in Aphelion, and when in Perihelion ? (99).

45. (*a*) Explain the cause of the appearances termed eclipses. (59, 60). 10

(*b*) Under what circumstances will a total eclipse of the moon take place ? (69).

46. Explain the apparent paradox contained in the following statement:—A telegram which left Bombay *this morning* was delivered in London *yesterday evening*. (29) 7

1873.

47. Define the following astronomical terms:— 10

Equinoctial, Declination, Ecliptic, Line of Equinoxes, Obliquity of Ecliptic.

48. State Kepler's Laws. (Appendix). 5

49. What is the average length of a Degree of Latitude? Where is it shortest, and why? (3). 10

50. Explain, clearly, how the semi-diurnal tide is produced. 10

1874.

51. Name the bodies comprised in the Solar System and arrange them in the order of their distances from the Sun (95). 10

52. A transit of Venus will be observed on the 9th of December 1874 by numerous European and American astronomers from about 75 different stations, at an expense of about £200,000. What astronomical problem has this great inter- 10

national expedition undertaken to solve? and what advantages are likely to be gained from the solution? (119).

53. Show that, in general, the latitude of a place on the earth's surface is the same as the altitude of the pole above the horizon of that place. (44). 15

54. Give a sketch illustrative of the Phases of the Moon. (55). 5

1875.

55. Define an *Ellipse*. Show how to draw one, marking the relative positions of the *centre* and *foci*. What are Kepler's Laws? (98, App.). 10

56. If the plane of the Moon's orbit coincided with the plane of the ecliptic, how many Solar and how many Lunar eclipses would occur in the year? (80). 6

57. What is the velocity of Light? From knowing this velocity show how the distance of the Sun may be ascertained by applying a discovery of the Danish Astronomer Roemer. (128). 6

58. Why are not all solar days equal ? 7
(40).

59. The Sun is nearer to the Earth in 7
winter than in summer : how then is the greater heat of summer to be accounted for ? (25).

1876.

60. Show by means of diagrams how 10
the apparent positions of celestial objects are affected by—Refraction, Parallax, and Aberration of Light.

61. What is the exact time of the 10
earth's Rotation on its axis ; and how many times does it rotate in the course of an ordinary year ? (38.)

62. What is the reason that the Moon 10
always presents the same face to the inhabitants of the Earth ? (86).

63. Give the *Rotation Periods* and 5
Periodic Times of the eight principal planets. (103).

1877.

64. Why does not a star always rise 8
at the same time ? Explain how the time

of a star's rising and that of its setting alter in the course of the year. (42).

65. Of what does the Solar System consist ? Name the planets in the order of their distance from the Sun. (95). 8

66. Describe Foucault's Pendulum Experiment to prove that the Earth rotates on its axis. (Appendix). 8

67. When it is noon in Bombay, what time will it be to a place 37° 26′ 40″ E., and to another 47° 30′ 20″ W. of Bombay? 7

1878.

68. Illustrate by a diagram the position of the Earth in the Solar System. (p. 69). 8

69. Explain what is meant by *longitude.* Why are the degrees of latitude and longitude not equal in length? (2, 3). 7

70. Explain the cause of the Tides, and draw a diagram showing the relative position of the Earth, Moon and Sun at *Neap* Tides. 8

1879.

71. Define *Equinox*, *Latitude*, *Orbit*, 12
Transit, and *Perturbations*.

72. Give the mean distances from the 10
Sun, and the times of revolution round
the Sun, of each of the planets.
(102,103).

73. What are *Satellites*? Name all 8
Jupiter's Satellites. (52).

74. What is meant by *Apparent solar* 12
day, *mean solar day*, *sidereal day*, and
mean lunar day? Give the length of
each.

75. In reading the Sun-dial, how 8
is it that some correction is generally necessary
to obtain mean time? And on
what days does the sun-dial indicate
mean time without any such correction?

1880.

76. The moon always presents the 5
same face to the Earth: can you explain
this fact? What are the Phases of the
Moon? (86,55).

77. What is the Physical condition of the Sun? What are the dark spots? Can you account for their apparent motion? (141,142). 7

78. State Kepler's Laws of Planetary Motion. (Appendix). 6

79. Earth, Jupiter, Mars, Mercury, Neptune, Saturn, Uranus, Venus. Rearrange these in the order of their nearness to the Sun, beginning with the nearest. Into what groups are these planets divided? (95, 100). 8

1881.

80. Give all the proofs you know of the Rotundity of the Earth, and its Rotation on its axis. (6, 12). 9

81. What changes would be produced on the Earth, if its axis were to place itself at right angles to the plane of the Ecliptic? (20). 8

82. Explain the causes of solar and lunar eclipses. Why do they not occur every lunar month? Why is a total solar eclipse visible only on a small portion of the Earth's surface? (59, 60, 62, 76). 9

1882.

83. What is meant by longitude and latitude of a place? Why are the degrees of longitude and latitude not equal in length? Why is noon at Madras half an hour earlier than at Bombay? (2, 3, 27). 8

84. How are the Tides occasioned? Explain Spring and Neap Tides. 10

1883.

85. Distinguish between apparent and mean noon and give approximately the greatest difference between them. 10

86. Explain the phenomena of the Seasons. (19). 10

1884.

87. What is the cause of an eclipse of the Moon? Why is it always Full Moon when an eclipse takes place? (60,61). 8

88. Explain the cause of the Tides. Why does the tide not always rise to the same height? 8

89. Shew by a diagram how the geographical position of a place is determined when its latitude and longitude are known. 8

1885.

90. Name the bodies comprised in the Solar System. Distinguish between Primary and Secondary Planets. (95, 107). 7

91 If a ship, sailing due west at a uniform rate, circumnavigates the earth in 600 days, what will be the interval of time between any two successive noons on board the ship? (30). 8

92. When is an Eclipse of the sun possible? Why is not a total eclipse observed at all places where the sun may be visible at the time? (59, 68, 76). 10

1886.

93. State the three Laws of Kepler, and mention what important conclusion Newton arrived at from the third law. (Appendix). 9

94. Which of the planets are attended by Satellites ? Name them and say how many has each. (106). 7

95. Give the general conditions under which Eclipses, lunar and solar, occur ; and explain clearly why we have sometimes partial and at other times total eclipses. (59, 60, 64). 8

1887.

96. When is Venus the Morning and when the Evening Star ? Why have the transits of this planet been observed with so much care ? (114, 119). 8

97. How many times is Mars smaller than the Earth? Describe its general appearance as seen through the telescope. (123). 7

98. Give two of the most obvious and convincing proofs of the rotundity of the Earth, and state clearly why the days and nights are unequal in length in different parts of the world. (6, 18). 8

1888.

99. Enumerate all the different bodies 9
that constitute the Solar System. Mention at least two particulars in which stars differ from planets. How do you distinguish between stars and planets at night? (95,96).

100. Explain fully, using a diagram, 9
the phases of the moon. (55).

101. How do you account for the fact 6
that the tide rises and falls twice daily?

1889.

102. Explain how the experiment of 9
letting fall a stone, or other heavy object, from the top of a high tower, may be employed to prove that our Earth revolves on its axis. Mention briefly two other considerations that point to the same conclusion. (12.)

103. Mention, without explaining, two 8
methods that have been used to ascertain the distance of the Sun. What are the dark spots of the Sun? What discovery did they lead to regarding the Sun? (138, 142).

104. What is meant by an Eclipse of the Moon? Explain the occurrence of the phenomena by a diagram. Why does the Moon always present the same half of her surface to the Earth? (58, 66, 86). 6

1890.

105. Mention the various bodies that constitute the Solar System, dividing the planets under their proper head, Exterior or Interior, and state opposite each the number of its moons. (95, 100, 106). 8

106. What is meant by a Transit of Venus? (117). 7

An Eclipse of one of Jupiter's moons took place at 11 A.M. at Greenwich, the phenomenon being observed at another town at 2 P.M. of its local time; find the longitude of the latter place. (33).

107. Explain the following:—Ecliptic, First Point of Aries, Retrograde Motion, Occultation, Right Ascension, and Satellite. (17, 172, 126, 173, 52, 107). 8

1891.

108. Give a general outline of the Solar System, mentioning all the planets, with their satellites, in order of their distance from the Sun. (95, 106). 8

109. Explain with a diagram the change of Seasons. (19). 7

110. Explain the phases of the Moon. (55). 8

1892

111. What is the reason that an Eclipse of the Sun can only take place at New Moon, and an Eclipse of the Moon only at Full Moon? (61). 9

112. What is the Sun made of? How has the length of its diameter been calculated? (143, 139). 9

113. Define in separate paragraphs the following terms:—Polar distance, Declination, Latitude, and Longitude. (171, 2). 10

1893.

114. Explain clearly why, as a rule, the days and nights are unequal, and 12

show that in two positions of the Earth's orbit the days and nights are equal all over the globe, and that at the equator they are equal throughout the year. (18).

115. Describe the appearance of Jupiter as observed with a telescope, and explain by means of a diagram the phenomena of occultations and eclipses of its satellites. What is the number of Jupiter's satellites? (125,126). 9

116. Define (1) the First Point of Aries, (2) inferior and superior conjunctions of a planet, and (3) conjunction and opposition of a planet. (172, 101). 4

117. Explain how to find out by observation whether a planet has its orbit within or without that of the Earth. (121). 5

1894.

Dhanjishah Hormasji Dastur; Prabhakar Ramkrishna Bhandarkar.

118. What facts go to prove that the earth travels round the sun once in a year? Describe an experiment illustrating this. (22). 12

119. Explain how the seasons depend 7
upon the difference in the lengths of the day and night. (19).

120. Explain clearly why the moon 13
changes her form from a crescent to a circle.

What fact prevents the monthly eclipses of the sun and of the moon ? (55,62).

1895.

Dhanjishaw Hormasji Dastur ; Prabhakar Ramkrishna Bhandarkar.

121. Mention all the motions of the 12
Earth, explaining the various astronomical phenomena produced by them. (11).

122 (*a*) What are meteorite sand 9
meteors ? What are the grounds for saying that comets are but swarms of meteorites ? (154, 158).

(*b*) How are astronomers able to determine the length of a planet's day ? (105).

123. While observing Jupiter at differ- 12
ent times, you see one of the satellites

(1) apparently touching the disc of the planet and gradually disappearing, (2) disappearing while it is yet at some distance from the disc, and (3) suddenly making its appearance some way off from the disc. Explain these phenomena with the help of a diagram. (126).

1896.

Dhanjishaw Hormusji Dastur ; K. K. Kapadia.

124. Give a brief and general description of the Solar System. (95). 8

125. How are solar eclipses caused ? When should we have a partial solar eclipse, a total solar eclipse, and an annular eclipse ? Why are lunar eclipses seen from a greater portion of the earth's surface than solar eclipses ? (59, 64, 76). 11

126. Explain how an interior planet in its path round the sun should vary in size and shape as seen from the earth. By what simple experiment would you illustrate your explanation ? (110, 112). 11

1897.

Dhanjishaw Hormasji Dastur ; K. K. Kapadia.

127. (*a*) Describe the appearance of the moon as seen through a telescope. (81). 15

(*b*) Fully account for the phases of the moon, drawing neat diagrams in illustration of your explanation. (55).

(*c*) Mention, but do not describe or explain, any other phenomena caused by the revolution of the moon round the earth.

128. How are the positions of the heavenly bodies determined ? Why are these determinations of great practical importance ? (174). 15

1898.

Nanabhai Ardesir Moos ; K. K. Kapadia.

129. What would happen if the Earth's axis were perpendicular to the plane of the ecliptic ? Give reasons for your answer. (20). 10

130. What are sun-spots supposed to be ? What kind of motion do they appear to have ? What does that motion indicate ? 10

What changes in their appearance do they present as they move along, and how would you represent these changes by a simple experiment? (142)

131. Explain how the eclipses, occultations, and transits of Jupiter's satellites take place. Draw a neat figure to illustrate your answer. (126) 10

1899.

Nanabhai Ardesir Moos ; K. K. Kapadia.

132. (*a*) Draw a diagram to illustrate approximately the distances, dimensions, and orbits of the planets and other bodies constituting the Solar System. (p. 72). 15

(*b*) State fully what you know about Lunar Eclipses. (60, 66, 67, 69, 74, 75.)

133. Define *gravitation*. Enunciate the laws of gravitation. (175, 176.) 14

Explain the principles of the calculation by which Newton proved the law of gravitation with reference to the motion of the moon round the Earth.

1900.

N. A. F. Moos; K. K. Kapadia.

134. (*a*) Fully describe and account for the apparent motions of the moon. Describe a simple experiment and draw a neat diagram in illustration of your answer. 20

(*b*) Clearly explain why the moon changes her form from day to day. (55).

135. State fully what you know about comets and meteorites. (147 to 158). 10

1901.

K. K. Kapadia ; H. M. Page.

136. State fully what you know about Solar Eclipses, drawing, as far as possible, neat figures, in illustration of your statements. (59, 61, 63, 64, 65, 68, 71, 73, 75). 14

137. Explain precisely how astronomical observations help us to determine the longitude of places on the earth's surface. 15

1902.

K. K. Kapadia : H. M. Page.

138. (*a*) Define Conjunction ; Phase ; Transit. (101, 55, 117, 126). 16

(*b*) Why are the Interior Planets so called? (100).

State fully what you know about the rotation, revolution, phases, seasons, and the apparent size of each of the Interior Planets.

139. Account for the variations in the length of days and nights, and fully explain how the seasons are caused. 18,19. 13

1903.

H. M. Page; Hormasji Navroji Bilimoria.

140. Why do eclipses not take place every month? Explain the occurrence of lunar eclipses with the help of a diagram. Describe the different kinds of solar eclipses. Make a sketch in black and white of the appearances of the sun's disc during the progress of (1) total, (2) partial, (3) annular eclipses of the sun. (62, 60, 66, 63). 11

141. Write all you know about—(1) sun spots, (2) comets, (3) the milky way, (4) nebulæ. What reasons have you for saying that comets are swarms of meteorites? (142, 147-153, 166, 167, 158). 14

1904.

N. A. F. Moos ; H. M. Page.

142. Explain the following terms:— Transit, occultation, gibbous, first point of Aries. (117, 126, p. 46, 172). 8

143. Suppose an eclipse of one of Jupiter's moons was observed to take place at Greenwich at 2 P. M ; while it was seen at two places A and B at 1 P. M. and 3 P. M. respectively. Find the longitudes of A and B. (33). 10

144. Give the names of every body that is included in what is known as the solar system. What is meant by "interior" and "exterior" planets? Name the former. 9

Draw two sketches to illustrate what is meant by "inferior" and "superior" conjunction. (95,100, 101).

1905.

N. A. F. Moos; H. M. Page.

145. What is the size of our earth? What is its distance from the sun? 10

Describe any experiment to prove that our earth is rotating on its axis. What is the velocity of the earth's rotation?

146. To what are the heat and light of the sun due ? How has the size of the sun been determined ? What are sun spots ? 10

147. How far is the moon from us ? 10

To what is its light due ? Why is it that the same half of the moon is always turned towards the earth while the other half is never seen by us ?

1906.

N. A. F. Moos ; H. M. Page.

148. State what you know about the sun's appearance, distance from the earth, and magnitude.

Show by a diagram how to account for the phases of the moon.

149. Explain the following terms :—

Ecliptic, right ascension, universal gravitation, aphelion, perigee, equation of time.

Draw neat sketches to illustrate clearly the following three phenomena, taking care to name all the essential parts of your drawings: —

(*a*) Total eclipse of the sun.

(*b*) Annular eclipse of the sun.

(*c*) Eclipse of the moon.

150. Why does noon at Bombay occur about an hour later than at Calcutta? What relation roughly does the Indian Standard Time bear to Bombay and Calcutta times?

How would you determine the latitude of Bombay?

151. Mention some reasons why we believe that our earth is rotating on its axis.

Draw the figure given in your text-book to illustrate the fact that the two motions of the earth are not in the same plane. What fact in nature results from this non-coincidence.

1907.

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152. What is the mean diameter of the earth and what is its distance from the sun? 8

Define terrestrial pole, equator, and parallels of latitude.

153. When it is 12 noon at Bombay it is 1h. 34m. P.M. at Rangoon. The longitude of Bombay being 72° 49′ east of Greenwich, find the corresponding time at Greenwich and the longitude of Rangoon. 10

154. There is a daily retardation in the time of the rising of the moon. What is the amount in time roughly of this retardation? Explain the phenomenon. 10

155. What are sun spots, chromosphere, corona, and red flames? Name some of the principal elements observed in the sun. How has the existence of these elements in the sun been proved? 12

156. State fully what you know about Comets and Meteors. 10

1908.

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157. Explain the following terms:— 8
Precession of equinoxes, asteroids, celestial equator, first point of Aries.

158. What is the distance of the sun from the earth? Knowing this distance 10

and the apparent size of the sun show how we can proceed to find roughly its diameter.

159. Describe the different kinds of solar eclipses with diagrams. Why do not eclipses take place every month? 11

160. Write explanatory notes on (1) Nebulæ, (2) Sun spots, (3) Comets, What reasons are there for believing that comets are swarms of meteorites ? 10

161. Explain how the longitude of places on the earth's surface is determined by astronomical observations. 11

* * *

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